ANALYSIS OF APOLLO LOGISTIC SUPPORT SYSTEM PAYLOADS TEST FACILITY REQUIREMENTS

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OFFICE OF THE CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY
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PREFACE

This is the report of a study conducted by the Office of the Chief of Engineers, U. S. Army, at the request of the National Aeronautics and Space Administration. The purpose of this study was to analyze the Apollo Logistic Support System Payloads test facility requirements; to determine the capability of existing chambers to handle the test requirements; and if modifications were necessary to provide the required capability, to determine the feasibility of making such modifications, the estimated cost of modification and the approximate time for construction of the modifications.

This study began on 1 July 1964 and an interim report was submitted on 5 October 1964. The interim report was reviewed by NASA; comments and supplementary information was furnished to the Office of the Chief of Engineers.

Included in this report are engineering feasibility analyses and concepts which have been developed for meeting various test facility requirements. These analyses and concepts were used in evaluation of chamber capabilities, and determination of scope of chamber modifications and cost estimates contained in this report. Also included is a tabulation of the capabilities of existing and proposed large chambers and a nuclear power test facility which were considered to have potential capability for meeting the requirements of the Test Philosophy and Outline Test Program for Apollo Logistic Support System Payloads.

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CHAPTER I

INTRODUCTION

The Office of Manned Space Flight, NASA, by letter dated 26 June 1964, requested the Corps of Engineers to conduct a study to analyze the various chambers in this country with respect to their capabilities to fulfill the test facility requirements of the Apollo Logistic Support System (ALSS) Payloads. The study entailed the evaluation of existing chambers to determine which, if any, could handle the test requirements, the modifications necessary to provide the required capability, the feasibility of making such modifications, the estimated costs of modification and the approximate time for construction of the modifications. The scope of chamber modifications and cost estimates were to be developed in two phases: (a) Requirements and costs to carry out the testing of major systems and (b) requirements and costs to carry out the combined systems testing.

The letter of authorization and the work statement are contained in Appendix A. The test facility requirements for the Apollo Logistic Support System Payloads are contained in the document "Test Philosophy and Outline Test Program for the Apollo Logistic Support System Payloads" dated May 1964. This document is contained in Appendix B together with changes in equipment dimensions and amplification of requirements obtained at a meeting with NASA, Office of Manned Space Flight on 27 July 1964 and subsequent thereto.

This study was conducted by the Advanced Technology Branch, Engineering Division, Directorate of Military Construction, Office of the Chief of Engineers.

Data needed to evaluate the capabilities of Large Chambers and the Nuclear Power Test Facility were tabulated and are shown in Appendix C and D.

An evaluation was made of the engineering feasibility of the test requirements stated in paragraph 8.3.1. "Vacuum Test Facilities" and paragraph 9 "Combined Systems Testing", with the exception of the dynamic tests in paragraph 9.2.3. Provision for the dynamic tests is not required in the chamber. Concepts were developed as necessary to determine the feasibility of the test requirements and compatibility with other test requirements. This included such items as the treadmill and simulation of movement of the solar simulation "sun". These concepts are included in Chapter IV and were used for determining scope of chamber modifications and cost estimates. If, after evaluation of the test requirements, an item was determined to be neither feasible nor compatible with other requirements, a suggested alternative was developed and is included in the report.

After determining the feasibility and compatibility of test requirements, an evaluation was made of existing chambers to determine which had the capability to fulfill the test requirements. The analysis was made on the basis of determining modifications necessary to make any particular one chamber capable of handling the test requirements. The test requirements in paragraph 8.3.1 "Vacuum Test Facilities" were considered for provision in a single chamber for Major Systems Testing. The additional test requirements in paragraph 9 "Combined Systems Testing" except for the dynamic tests were considered for inclusion in one chamber. The evaluation of chambers is covered in Chapter V.

The scope of chamber modifications and cost estimates were developed in two phases. The first phase considers the requirements and costs associated with the testing of major systems; the second phase considers requirements and costs associated with combined systems testing. Each phase includes the approximate time for construction of the modifications. The chamber modifications and cost estimates are included in Chapter VI.

Conclusions reached pertaining to the test requirements are stated in Chapter II. The conclusions based on the overall study are contained in Chapter III.

CHAPTER II

ENGINEERING SUMMARY

This chapter summarizes the results of studies made to determine engineering feasibility of meeting test facility requirements for both Major Systems Testing and Combined Systems Testing, as specified in the Test Philosophy. The chapter also summarizes results of an analysis of space simulation chambers, both existing and under construction, to determine suitability for testing ALSS payloads. This analysis included development of concepts for chamber modifications to determine the scope and cost of such modifications. A summary of current information on chamber characteristics and operational status is presented in Appendix C and D.

A. GENERAL

The prime requirement of the type of test facility under consideration is to simulate to the maximum degree environmental conditions as presently known or postulated which would be encountered on the lunar surface by man and by the equipment being tested. Some of these conditions cannot be duplicated at the present time irrespective of the cost or the size of the test facility. Those which are not feasible to simulate in a large test facility are:

Soft x-rays and proton bombardment effects of solar events.

Meteoroid impact and ejecta effects.

The 1/6 gravity of the moon.

Thus, in the design of any facility it is necessary to eliminate that which is impractical to accomplish and to compromise that which, although possible, is not economical to duplicate in its purest sense. A chamber, therefore, will not possess the characteristics for conducting "perfect" tests but rather must approach closely the desired characteristics within economic and practical limitations. The problem then becomes one of attempting to evaluate desirability versus the essentiality of increased test capability and its worth to the actual system development.

B. TEST FACILITY REQUIREMENTS

The test facility requirements of the Test Philosophy present many interfaces requiring trade-offs for integration into a facility. The feasibility of meeting these test requirements is summarized below.

Radiation Heat Sink

A space sink temperature of 100°K is attainable by means of liquid nitrogen panels. Any attempt to closer approach the actual 4°K space temperature is not warranted due to the infeasibility of producing this temperature on a large scale. Furthermore the transfer rate from a 300°K (80°F) source to a sink approximating 105°K is only about 1¼ percent less than the transfer rate to a 4°K sink. The percentage is even less for a higher temperature heat source.

Solar Radiation

Simulation of solar radiation presents many complex factors requiring analysis of the qualities which are desired and the various trade-offs which can be made considering feasibility and economy.

In this study various systems of solar simulation were analyzed. These included a top "sun", top and side "sun", top, side and intermediate "sun", full "sun" extending from lunar plane level to overhead, and a moving "sun".

In evaluating a three position solar simulation system, cost of the individual modules and associated ignition and cooling equipment is a major factor since the three positions require three times as many modules as the moving "sun" concept. A "top-and side-sun-only" arrangement does not provide the test flexibility possible with either a "moving sun" or the three position "sun". In the use of a single array of lamps extending from the side sun position to the top sun position, aside from the additional cost of lamp modules and associated equipment, a complex system for varying lamp orientation would be required to form a proper beam having any desired azimuth. Such a system would not obviate the necessity for a turntable or other means of orientation of the test object. Hence, such a concept was not developed in detail for further study.

A concept for a moving sun has been developed although realization of such a concept will require further design development prior to initiation of design for construction. Although a moving sun is feasible, movement of the solar simulating source is only attainable with some sacrifice in reliability, economy of operation and ease of maintenance, and possibly some sacrifice in accuracy in beam direction and collimation. Design features requiring further development include:

Means of distributing electric power, control circuitry, and coolant lines in a flexible link to the movable array.

Means of driving the array.

Means of providing rigidity of the lamp arrays within space limitations.

In the moving sun concept presented on drawing VI-6 the array is mounted in a gimbal ring. This permits variation in the beam angle in the plane of the arch support frame and also transverse to the arch frame without the necessity of mounting the test specimen on a turntable.

The moving sun concept is limited to use of the Xenon lamp and supporting optics, and to the spectrum produced thereby. For fixed position, either carbon arc, or mercury-xenon lamps could be used.

A moving sun capable of both horizontal and vertical azimuth orientation is preferred over a system which would employ a vertical azimuth sun and a turntable system, and the latter system is preferred to other methods which would require reorientation and repositioning of the test object.

Earth Shine

Earth shine may be provided by adding small tungsten filament lamps in the basic lamp modules. The energy required to simulate earth shine is very small when compared to that needed to simulate solar radiation.

Infrared

Extension of the 20 foot diameter spot of "spectral quality" simulated solar radiation to an area of 20 by 49 feet by an "infrared" or thermal beam, is feasible by using tungsten lamps. Tungsten lamps without filtration will provide illumination as well as the desired thermal effects and are therefore more realistic than infrared radiation alone.

Vehicle Exercise System

Many variations of vehicle exercise systems were considered. The more desirable system is one which would provide actual vehicle movement beyond merely short forward, backward, or limited turning motions. This would require a sufficiently large chamber to permit driving the vehicle around in a circle.

A treadmill is limited in its ability to accomplish vehicle exercise in that provision cannot be made for vehicle turning, including vertical and lateral wheel articulation. In addition, it is not considered reasonable to incorporate a treadmill, of the size required for the Lunar Roving Vehicle (LRV), in a vacuum chamber. This is due to the problems associated with belting, drives, heat dissipation of drive equipment located within the chamber, and sealing for operation in vacuum.

A wheel drive system or chassis dynamometer has greater capability to simulate traverse over rough terrain. An individual wheel drive system has the disadvantage of presenting an improper footprint, but it does have the advantage of drive motion imparted to or from the wheel thus testing the wheel in conjunction with the axle, and suspension system.

The axle dynamometer represents the simplest system. Its major disadvantages are the lack of actual vehicle exercise, the loss of thermal conductivity between the wheel and the surface, and the absence of tractive forces between the wheel and the surface.

Any testing program for the LRV must eventually include exhaustive testing of components of the full LRV under atmospheric conditions. Tests of components, individually and in combination, must also be performed in chambers adequate to accommodate the test items and to simulate lunar conditions in varying degree. Having performed these tests, including model tests, either a wheel drive system or axle dynamometer system could then be utilized in a large chamber for final testing. In view of these considerations the axle dynamometer system is favored due to its simplicity.

Lunar Soil Simulant

The incorporation of a lunar soil simulant in a chamber would provide a desirable trafficability test surface and realistic thermal and visual conditions. A practical chamber size essentially eliminates extensive trafficability studies, thereby reducing the need for this type of surface simulation. Because of the magnitude of the problems associated with this large mass of soil simulant in a test chamber other methods of obtaining the required test conditions were examined. It is considered more feasible to provide a rigid surface with thermal characteristics approaching those of a soil simulant, and to conduct trafficability tests under controlled or selected atmospheric conditions with test vehicles specifically designed and scaled for the particular test environment. Reinforcing this approach is the fact that reduced gravity for vehicle testing can be neither reproduced inside nor outside of the chamber, and test objectives would have to be adjusted in either environment. Hence, it is concluded that a lunar soil simulant is not needed in the test facility based on current requirements established for the ALSS Payloads test program.

Thermal Simulation of Lunar Surface

If a soil simulant is not provided, the surface of the lunar plane should be treated to obtain the proper absorptivity, emissivity and the resultant a/e ratio. Specific heat and conductivity of the lunar plane sub-surface can be partially simulated by design and selection of materials to obtain some degree of passive thermal control. However, auxiliary heating and cooling of the floor will be necessary to simulate lunar surface temperatures during both day and night.

Thermal Loads

The Test Philosophy requirement for a 10KW heat sink capacity is overshadowed by other demands which may total 1400 KW or more. Therefore, this test item requirement is insignificant in the overall heat sink load.

Vacuum Pumping

A vacuum of 10^{-8} torr is realistic and attainable in a large chamber when not subjected to significant outgassing loads.

Calculations indicate that the vacuum requirement of 10^{-5} torr with tests in progress will create some difficulty because of anticipated oxygen and hydrogen leakage and outgassing. Other sources of leakage and outgassing can be accommodated provided care is exercised in the design and materials selection for test items. If it is not feasible to provide helium cryopanels or additional diffusion pumping, it may be necessary to relax vacuum requirements from 10^{-5} torr to 10^{-4} torr. Paragraph 6.3 Criteria for Vacuum Test Facilities, COMPONENT TESTING, makes provision for materials testing at 10^{-10} torr on component testing. This leaves only those vacuum considerations associated with thermal and mechanical adequacy of the test item in the proposed chambers. It is considered that these latter two features can be adequately evaluated at a pressure of 10^{-4} torr.

100 Operations of Two-Man Air Lock

From the standpoint of ruggedness, there should be no problem associated with 100 operations of two-man airlock doors. There also should be no problem associated with the mechanical pumping for this type of operation on a repeated basis.

Two Weeks Operation

Most of the chambers under consideration are rated for operation in excess of two weeks. One difficulty which may be encountered here is the accumulation of excessive condensate on helium cryopanels where sustained outflow of leakage occurs, e.g. oxygen outgassing, thus necessitating additional cryopanel area to provide for reduced cryopumping efficiency due to the condensate buildup.

View Factor

Thermal balance in space equipment is largely dependent upon the radiation of its excess heat to deep space. An item of equipment on the lunar surface can radiate to 4°K space for a near full hemisphere providing its view is not obstructed by other equipment placed in close proximity to it. Simulation of this view factor in a chamber is achieved only to the degree to which the view of the heat sink panels remains unobstructed. A similar situation exists with respect to the lunar plane. Therefore, the larger the chamber, the greater the possibility of providing the test object with a better view of the heat sink and lunar plane resulting in more realistic simulation. In this respect a moving sun covering a smaller area is preferable to a series of fixed banks of solar modules.

Working Envelope

The working envelope includes the volume occupied by test equipment, instrumentation and astronauts, and the proper spacing from test objects to chamber surfaces. The Test Philosophy specifies 5 feet between chamber surfaces and the test object. However, other considerations such as the moving sun may necessitate an increase in size over the requirements stated above. The large area occupied by the solar and infrared panel will require spacing up to 40 feet from the test object to permit radiant cooling of the heated test object. Also close proximity to the liquid nitrogen cooled walls would preclude simulation of a view of the lunar plane. The working envelope must also make provision for Major and Combined Systems Testing; however, in the former instance the LEM and LRV will not be tested in tandem. In no instance is it considered necessary to provide the space required for a tandem concurrent arrangement of the LEM Truck, LRV and vehicle exercise system. Based on the above considerations the minimum diameter of the working envelope required for Combined Systems Testing is 110 feet. This is based on provision of features such as thermal panels to improve the view factor.

Manrating

The criteria for manrating of Space Environment Simulation Chamber A has been selected as a standard of criteria for manrating in this study. The manrating of any other facility will require the installation of a complete system of emergency repressurization, environmental controls, manlock, instrumentation and other features required for human occupancy.

Equipment Airlock

The Test Philosophy contains the requirement for an equipment airlock for Major Systems Testing to accommodate the largest payload system; for Combined Systems Testing either an airlock or other opening is required to accommodate a loaded LEM Truck. The length and width of the airlock is determined by the dimensions of the LEM Truck Payload and the height is determined by the LRV since only one module of the LRV need be considered for sizing the airlock. An equipment airlock will serve to provide a means of entry of equipment to the chamber without the necessity for repressurization of the chamber. It also can serve as a less sophisticated test chamber or to provide supplemental space to the main chamber. The provision of an airlock for entry of small auxiliary equipment into the chamber is desirable; however, an airlock sized for entry of large equipment such as a LEM Truck Payload or LRV into the chamber seems questionable. The setup of such equipment requires extended periods of time and the connection of many instrumentation items which could better be performed under atmospheric conditions. The evaluation of chambers and modifications, however, have been based on the provision of an airlock sized for the largest payload in accordance with the Test Philosophy.

C. SPACE SIMULATION CHAMBERS

The review of existing chambers and those under construction, indicates that none of the facilities is adequate in all respects to meet the test facility requirements of the Test Philosophy. A summary of chamber capabilities and feasible modifications to these facilities is given below.

Space Propulsion Facility, NASA Lewis Research Center, Plumbrook Station, Ohio

This facility was designed primarily to test nuclear power systems. The chamber is constructed of a concrete outer shell with a 100 foot diameter, 122 foot high aluminum inner shell which serves as the heat sink. Between the concrete and aluminum shells there is an annular space in which the doors to the inner shell move and are stored when the doors are open. The location of diffusion pumps in the chamber floor limits the usable working surface for placement of the test objects to an area 50 feet by 100 feet. The facility is under construction with completion scheduled for early 1967. Although construction has been initiated it is possible to incorporate design changes if an early decision is made to do so.

The design does not now incorporate solar simulation but it is planned that it will be included and installation will be completed in 1967. The solar modules contemplated will be usable for either a fixed top or side sun 500 square feet in area and will be "canned" type suitable for containment within the radiation shield. The chamber does not have provision for a turntable for test vehicle orientation. Two large doors each with a nominal opening of 50 feet by 50 feet are located diametrically opposite in the sides of the chamber.

The 50 foot by 100 foot working surface is of sufficient size to meet the requirements of Major Systems Testing and will permit a deployment test of the LEM Truck and the LRV for Combined Systems Testing. However, other factors must be considered and without a moving sun, a turntable, or other means of test vehicle orientation, proper irradiation of the test vehicles cannot be achieved. A turntable has been ruled out because of the size of the turntable that would be required for Combined Systems Testing.

A moving sun concept, including infrared panels, has been developed and is incorporated on the drawings in Chapter VI showing the modifications required to make this facility suitable for the ALSS Payloads test program. Provision of the moving sun would require an increase in chamber diameter to allow room for the sun and sufficient work space for Combined Systems Testing.

In addition to the space required for a moving sun, helium cryopanels must be added to handle the increased gas load to maintain a vacuum of 10^{-5} torr. The full floor area in the chamber is needed to provide the minimum area in which test objects can be placed and to provide a satisfactory view factor. This would require relocation of the diffusion pumps from the floor to the walls and necessitates their placement within the annular space. An internal chamber diameter of 110 feet has been found to be the minimum for providing the above needs. This would necessitate redesign of the chamber shell and supporting floor. To provide space in the sidewall annulus for the diffusion pumps and necessary relocation of both chamber main door, the annular space must be increased from the present 15 feet to 20 feet. It is considered that any further increase in chamber diameter would make modification of this chamber both infeasible and impractical due to further enlargement of the concrete dome.

For Major Systems Testing an equipment airlock is required by the Test Philosophy. One of the advantages of an airlock is that it could supplement the space capacity of the chamber and it was considered for this purpose in the Space Propulsion Facility. However, addition of such space external to the main chamber diameter would not result in a reduction of the proposed chamber diameter.

An equipment airlock attachment to the Space Propulsion Facility presents a complicated design problem. Fitting a fixed airlock to the chamber would reduce the size of the chamber opening and would compromise the radiation shielding which is provided by the concrete door.

It is necessary to consider compatibility of the ALSS Payloads test facility requirements with the nuclear testing capability for which the Space Propulsion Facility was designed. Materials for use in the chamber must be compatible with the nuclear testing requirements. A movable equipment airlock of the size required for passage of test objects into the chamber has been included.

An extension of the building is also shown on the drawings in Chapter VI to provide space in the assembly area to compensate for that occupied by the equipment airlock when the airlock is being utilized. A separate building addition is also required to provide for storage of the equipment airlock when not in use.

Manrating of the Space Propulsion Facility can be accomplished. However, manned occupancy of the chamber and airlock must await a period of time following any nuclear testing. This time is dependent upon the rating of the nuclear device and may extend as long as 45 days. Chamber A is the only large facility rated for manned occupancy. The Space Propulsion Facility could be similarly equipped in order to meet the ALSS Payloads test facility requirements. The provision for manrating requires a manlock, environmental control system equipment and instrumentation, addition of space for the equipment and instrumentation, and the addition of a repressurization system with quick response.

Additional instrumentation will also be necessary for the test vehicles, particularly the LRV.

The present design of the chamber provides for cooling of the working surface. A means of heating together with its associated controls, will also be required.

The modifications enumerated above are considered to be the minimum essential to meet the test facility requirements contained in the Test Philosophy. They have been predicated on the use of the facility as a dual purpose facility incorporating the ALSS Payloads requirements and still retaining the nuclear propulsion testing capability. These modifications would result in a major redesign of the facility and it is estimated that it would take a period of six months to accomplish the redesign. If design is initiated in the near future, incremental design could be accomplished for some areas and furnished to the current construction contractors as completed. This redesign and the construction changes would result in a delay of about one year in completion of the project. The cost of modifications, including the redesign and added construction costs is estimated to be $26,623,000 for Major Systems Testing and $24,298,000 for Combined Systems Testing. Construction impact costs are not included.

One major consideration in redesign, and the major pacing factor, is the provision of a moving sun. It is not reasonable to expect that this system can be developed and designed within a six month period; however, provision can be made in the basic structure for its future incorporation. The moving sun concept should, with design development, be feasible; however, there are complexities which should not be underestimated. The decontamination of the structure associated with the moving sun will be a major factor in the Space Propulsion Facility.

Space Environment Simulation Facility, Chamber A, NASA Manned Spacecraft Center, Houston, Texas

This facility was designed for spacecraft testing and astronaut training within a simulated space environment. The facility presently under construction with completion scheduled for 1965, contains two chambers - Chamber A and Chamber B. Chamber B is the smaller-35 feet in diameter-and because of its size has been eliminated from further consideration for the ALSS Payloads test facility requirements.

Chamber A is 65 feet in diameter and 117 feet high. It will contain a 45 foot diameter rotating lunar plane and solar simulation consisting of a side sun and top sun. The temperature of the lunar plane is controlled to provide either a hot or a cold surface. It is manrated, has a liquid nitrogen heat sink and helium cryopumping.

Chamber A is of sufficient size to accommodate the individual ALSS equipment items for Major Systems Testing, except for an LRV 46 feet in length. If the length of the LRV were shortened to approximately 43 feet, the chamber could accommodate the vehicle. Chamber A is not of sufficient size in which to conduct Combined Systems Testing. Addition of an equipment airlock, though providing additional space, will not permit the vehicle maneuverability desired, solar irradiation of the test vehicles or the required view factor.

The solar simulation system will not simulate movement of the sun except for sequential programming of modules in the fixed top and side suns. Arrangement of the chamber does not lend itself to installation of a moving sun. However, the side sun and the top sun can be increased in size to partially meet the ALSS payload test requirements. It does have the advantage of a rotating table for orientation of the test item with respect to the two sun positions.

Inasmuch as Chamber A does not have an airlock for vehicle access a concept was developed for incorporating this requirement of the Test Philosophy. Although such a modification is possible its incorporation is not recommended due to the complexity of such an addition and the loss of utility and flexibility of the facility.

Chamber A cannot fully meet the ALSS test facility requirements. With additional solar simulation, lunar plane temperature control, addition to the helium and nitrogen systems required for the ALSS equipment gas loads, and a dynamometer system, Chamber A could be utilized on an "as-is" basis for Major Systems Testing. The cost of adding these additional systems is estimated to be $4,602,000. The time required is estimated to be two months for design and a period of four months for installation after receipt of procured equipment.

Other Chambers

The size of the working envelope is of prime importance in evaluating the suitability of chambers for the ALSS test facility requirements. The Space Propulsion Facility is the largest and the MSC Chamber A is the second largest of those facilities of the type required for the ALSS Payloads test program. The size of Chamber A, is marginal for Major Systems Testing and the Space Propulsion Facility, though larger, would require an increase in size for Combined Systems Testing. All the other facilities, being smaller in size than either of these two, will not meet the space requirements. An investigation of the smaller facilities indicates that it is not feasible, either by an increase in physical size or by the addition of an airlock, to modify these chambers to obtain the space required.

CHAPTER III

CONCLUSIONS

The purpose of this study was to evaluate the engineering feasibility of test facility requirements and to determine the capability of large environmental test facilities to fulfill these requirements for ALSS Payloads. Environmental facilities, both existing and under construction were considered, including the feasibility and scope of modifications required. Determination of availability of facilities was not a part of this study although it would be a key factor to be weighed in considering modification of an existing chamber or construction of a new facility. The evaluation, summarized in Chapter II, indicates that certain changes in test requirements are necessary, but generally it is feasible to meet the Test Philosophy. The new concepts necessary to accomplish the various requirements have been developed in this study.

From this study it is concluded that there is no chamber in existence or under construction which can satisfy all the test facility requirements either for Major Systems Testing or Combined Systems Testing as outlined in the Test Philosophy and Outline Test Program for Apollo Logistic Support System Payloads dated May 1964. However, two of the chambers could conceivably be modified, with certain compromises in test capability, for this program. These chambers are the Space Propulsion Facility, Lewis Research Center, Plumbrook, Ohio and Chamber A of the Space Environment Simulation Facility, Manned Spacecraft Center.

Only the Space Propulsion Facility, scheduled for completion in early CY 1967, is of sufficient size to provide the surface area to accommodate the ALSS Payloads items for both Major Systems Testing and Combined Systems Testing. Other requirements, however, necessitate enlargement of this facility to meet the ALSS Payloads testing needs. This will call for major redesign of the facility. Unless a decision to incorporate the dual testing function is made in the very near future, construction will have progressed to the stage where a large amount of new construction will have to be removed and it will no longer be reasonable to consider redesign.

If the maximum length of the LRV were reduced to approximately 43 feet, MSC Chamber A could accommodate all the individual items for Major Systems Testing. However, Chamber A cannot meet all the test facility requirements of the Test Philosophy. Modification of MSC Chamber A to provide a moving sun is neither practical nor economical.

The addition of an equipment airlock to MSC Chamber A to meet the Major Systems Testing requirement is an impractical modification which would result in a loss of space and inefficient use of the facility. The addition would be complicated by the large 40 foot diameter side opening door and would be of excessive size due to the need for compatibility with the door.

CHAPTER IV

ENGINEERING REQUIREMENTS

A. SOLAR SIMULATION

Test Philosophy Requirements

The detailed requirements of the Test Philosophy are set forth in Appendix B. Insofar as solar and thermal radiation simulation requirements are concerned, they may be summarized as requirements for materials testing through Combined Systems Testing. A Combined Systems Test is defined as a payload complete with LEM Truck, having the following maximum dimensions:

LEM Truck Loaded 33 feet diameter x 22 feet high

ALSS LRV 17 feet wide, 14 feet high and 46 feet long

Radiant flux of 140 watts per square foot is required with a 20 foot diameter solar simulating beam with the desirable characteristics for variable positioning and supplementing thermal lamp system to increase the irradiation area from that of the 20 foot diameter solar beam to an area 49 feet by 20 feet comprising both the solar spectral and thermal beams. Five foot clearances between test items and chamber walls are required. The solar simulating beam is to approach the solar spectrum in quality, collimation, uniformity, etc., at least to the degree achieved in the NASA Manned Spacecraft Center, Chamber A.

Although there appears to be a difference between the desired capability for Combined Systems Testing as stated and specific requirements delineated in the Test Philosophy for solar radiation simulation, if as indicated to date in the ALSS payload studies the LRV maximum length may be 25 feet or less, the Combined Systems Test could be conducted under exposure to the combined solar spectrum simulating and thermal beams (i.e. total area of irradiation of 20 feet by 49 feet). For vehicle growth to 46 feet in length, the length given in the Test Philosophy, the radiation beams would not cover sufficient area to completely irradiate simultaneously all components of a Combined System Test.

The radiant flux required is 140 watts per square foot, or 1510 watts per square meter, and exceeds the value for the solar constant at the mean earth orbital distance from the sun which is about 130 watts per square foot, or 1396 watts per square meter. This excess capacity in the intensity of radiation provides flexibility in test operations, and assures minimal operational effect of lamp degradation with use.

The spectral quality of radiation desired for the solar spectrum simulation beam is the zero mass USNRL solar spectral irradiance distribution (ref: page 15-16, Handbook of Geophysics, the MacMillan Company, New York, 1960).

Characteristics of Solar Radiation

In the simulation of the lunar environment, solar radiation is an environmental factor which is significant from the standpoint of thermal effects upon irradiated surfaces, and from the deteriorating effect of the high quantum energy range of the spectrum (short wave length ultraviolet). The relatively high energy per quantum, high absorption coefficient of materials, and the intensity of ultraviolet radiation in space can produce significant effects on certain materials. Another characteristic of ultraviolet radiation is that it is absorbed by many surfaces which are highly reflective in the visible and near infrared portions of solar spectrum, hence may in specific configurations play a critical role in the thermal balance of the test specimen surface. It is not proposed to duplicate effects of solar proton bombardment in a large chamber, since it is feasible to reproduce these effects in small-scale experiments. Likewise, soft x-rays are not proposed for the electromagnetic spectrum to be simulated in large lunar environmental simulators.

The sun is a gaseous body within which nuclear transformations liberate energy to maintain its mass at elevated temperatures. The luminous envelope has an apparent (black body) temperature of about 6000°K. The sun is not precisely a black body, that is, it does not radiate with a spectrum following Planck's radiation law exactly, having a Stefan-Boltzmann emissivity factor of approximately 0.99.

Monatomic gases when thermally or electrically excited emit radiation as a result of electron transitions from excited or ionized states to the ground state of a lower state of excitation. With each permitted transition there is a discrete wave length emission associated. In the photosphere of the sun, there are a sufficient number of elements and states of excitation and ionization such that the resulting radiation spectrum approaches that derived from Planck's radiation law at a black body temperature of about $6000^{\circ}K$.

About 97% of the solar energy is emitted in the spectral range of from 0.3 micron wave length to 3 micron wave length (in which the visible range is included) with about 2.1% of the energy in wave lengths greater than 3 micron wave length, and 1.2% in wave lengths less than 0.3 micron. At the mean earth-sun distance, the spectrally integrated solar radiant flux is 1396 watts per square meter normal to the sun's rays.

Thermal Effects in Simulating Solar Radiation

The desirability for simulating as realistically as possible the solar spectrum envelope is based on two fundamental phenomena:

a. The ratios of absorptivity at the incident wave length to emissivity at the test specimen surface temperature vary with the frequency (or wave length) of incident radiation.

b. Ultraviolet radiation (higher quantum energy level) i.e. wave lengths of from 0.2 microns to 0.4 microns is more effective in causing materials degradation than lower frequency radiation (visible and infrared) of wave lengths of from 0.4 microns to 6 microns.

Irradiated surface equilibrium temperatures are a result of the interrelationships between radiation total intensity, spectral quality, incident angle, absorptivity, emissivity, and steric factors (angles of view) and the space sink temperature; and because of the first phenomenon, spectral quality is a major factor in simulating thermal effects of solar radiation.

In the case of the second phenomenon, the deteriorating effects of ultraviolet radiation on materials are not critical in systems testing, since this effect will be evaluated in most instances during component tests prior to systems testing.

The other characteristics of simulated solar radiation, aside from spectral quality, which must be considered are: degree of collimation, uniformity, total radiation intensity and incident angle.

At the earth's orbit, the sun subtends an angle of 32 minutes as viewed from the earth. This means that the decollimation half angle is no greater than 16 minutes. There are several effects associated with collimation. One concerns the effect of shading of components by overhanging parts, and the intensity of the simulated solar beam. The poorer the collimation the greater will be the variation of beam intensity as a function of distance from the source. Performance of solar collectors in solar simulating environments will also be influenced by the degree of beam collimation.

Variations in the beam uniformity in the plane normal to the direction of beam projections would subject different areas of the test specimen to different radiation intensities.

Incident angle of solar radiation is significant in evaluating effects of solar radiation throughout the lunar diurnal cycle. On the lunar surface the intensity of sunlight will not vary with the sun's position on the celestial meridian at any point the sun is seen completely above the horizon. Thus portions of equipment whose surface is normal to incident rays will be exposed to full radiation intensity irrespective of the sun's position above the horizon. The radiation which may be absorbed will vary as the cosine of the angle of incidence of incoming rays onto the equipment surface areas.

To evaluate the thermal effects of these characteristics for simulated solar radiation, the nature of heat transmission in space must be considered. In a perfect vacuum environment heat transmission from one body to another through space is by radiant energy transmission only. This transmission rate is given by the Stefan-Boltzmann equation, which for the purpose of this analysis (neglecting reflection to source and re-reflecting to receiver) may be expressed as:

$$\dot{Q} = A_n F a \epsilon \sigma (T_s^4 - T_b^4)$$

$\dot{Q}$ = heat(energy) transfer rate

A_n = projected area of the body B on a plane normal to radiation flux from Source S, $A_n = \sum \cos \varphi_a \Delta A$

F = view factor of S viewed from B

a = absorptivity of B α = absorptivity of S

ϵ = emissivity of S e = emissivity of B

σ = Stefan-Boltzmann constant

T_s = source temperature, absolute scale

T_b = body temperature, absolute scale

φ = angle of incidence of radiation on differential area

Should S represent a sink at temperature less than B, flow would be reversed from B to S.

In the equation it is seen that the heat flow to the test specimen will vary as:

Angle of incidence of the simulated solar radiation.

The decollimation angle for the simulated solar radiation. (In this equation above, it is expressed as a view factor (F)).

Absorptivity of the body. (Here a mean value is assumed, or more precisely $\Sigma a_n P_n$ for a given temperature, where a_n = absorptivity at wave length n, P_n = fraction of radiation at wave length n, since absorptivity may differ at different wave lengths.)

Difference of 4th power absolute temperatures.

Following the same quantitative law, heat energy from the specimen radiates to the surroundings of lower temperatures or for example, if in the presence of a simulated lunar soil, the specimen is at a temperature lower than the soil surface, heat is transmitted to the test specimen by the same radiation law.

Thus from the foregoing, it is evident that deviations from any one of the following characteristics from the corresponding values actually represented on the lunar surface will affect the thermal balance, and in consequence reduce the degree of environmental simulation, i.e.:

Spectral quality of the simulated solar radiation.

View factor of the simulated solar source (decollimation angle) from the test specimen.

Temperature of simulated deep space.

Absorptivity of simulated deep space.

Angle of incidence of simulated solar radiation.

To quantitatively evaluate the effect of deviations in these parameters from the lunar environmental values, it is necessary to use Stefan-Boltzmann's radiation law.

For example, on a typical lunar day, at equilibrium temperature of the specimen surface, heat absorbed from the "sun" equals that emitted from the surface to the heat sink of space, provided of course, that there are no internal heat producing or absorbing devices involved. The true space temperature is about 4°K; however, the boiling point of liquid nitrogen used in cryopanels is 77°K, hence the temperature for cryopanels approximates 77°K. Applying the radiation equation, $\dot{Q} = A_n F e \alpha \sigma (T_b^4 - T_s^4)$, where α is the absorptivity of space, taken as $\alpha = 1$, and e is the emissivity of the test specimen, it can be shown that an error of less than one degree of test specimen surface temperature (where the test specimen surface temperature is 200°K or higher) may be expected from a space heat sink temperature of 77°K instead of the true space temperature.

Similarly, it can be shown that at about 300°K test specimen temperature, a 10 percent error in surface temperature will be incurred when a 50 percent error is made in reproducing the view factor, a/e ratio or other linear factors of the solar simulation system.

Radiation Sources for Solar Simulation

For simulation of the sun's radiation spectrum electrically excited arc lamps have been used, (Carbon arc, Xenon arc, and Mercury-Xenon arc) which emit radiation in electron state transitions of excited atoms and ions.

Essentially two basic sources are available, one is the carbon arc and the other is the pressurized gas compact arc. Examples of these sources include:

a. 32 KW carbon arc units being fabricated for the Manned Spacecraft Center, Houston, Chamber "A" by the Radio Corporation of America. A comparison of a 16 mm carbon arc spectrum with the solar spectrum is shown in Figure A-1.

b. A 2 1/2 KW Mercury-Xenon (HgXe) compact arc available from the Westinghouse Electric Corporation having a spectral quality as shown in Figure A-2 and a 5 KW Xenon (Xe) compact arc available from the General Electric Company and the Westinghouse Electric Company on special order. A comparison of the 5 KW compact Xenon arc lamp spectrum with the solar spectrum is shown in Figure A-3.

The carbon arc most closely simulates the solar spectrum. The most significant deviation is the spectral peak at about 0.4 microns.

Carbon arc lamps use solid consumable electrodes which require provision for automatic rod feeding and daily loading of the rod magazines, and for exhaust of rod combustion products to minimize contamination of the optics.

The pressurized gas lamps are available with tungsten electrodes, in sealed quartz envelopes. They are subject to explosion failure, which is most probable on start up. Consequently, in an array of these lamps a few percent may fail in this mode in 500 hours of operation.

Degradation in intensity with operating life is experienced with this lamp, which operationally is compensated by increase in lamp operating voltage. With the Xenon lamp this degradation rate decays exponentially with operation, such that greatest degradation occurs in the first 100 hours of operation.

The Xenon lamp produces a spectrum which coincides well with the solar spectrum except for the infrared emission in the range between 0.8 and 1.1 microns. Where it emits 33 percent of its total radiant energy, as compared to about 18 percent for the solar spectrum.

The Mercury-Xenon lamp produces a spectrum resembling the Xenon lamp spectrum with superimposed peaks in the ultraviolet and visible wave length bands (0.2 microns to 0.6 microns), hence for some purposes may more closely simulate the solar spectrum than the Xenon lamp. But this lamp is apparently more restricted in orientation than the Xenon lamp, because of the tendency to more rapidly form deposits on the lamp envelope when used in other than design position.

The plasma arc is a compact arc type under development in which the pressurized gas is circulated through the lamp and electrodes and cooled externally, permitting higher excitation energy and potentially improved spectral simulation. Although the carbon arc most closely simulates the solar spectrum, with further development of the gaseous arc lamp, particularly of this externally cooled configuration permitting higher excitation energy, close simulation of the solar envelope may be possible with the gaseous arc lamp also. However, in this investigation, the externally cooled plasma arc lamps are not proposed for inclusion in a solar simulating system since they are still essentially developmental, have not been produced in quantity and little experience in operating them has been developed to date.

Optical Systems

Optical systems are required to collect as much of the lamp radiant energy as possible, and to collimate the radiant energy beam. Figure A-4 shows an optical system for a single compact arc lamp solar spectrum simulating module of the on-axis type. Instead of one lamp in the collection system, an array could be used.

These systems result, however, in the modification of the spectrum produced by the lamp or radiation source. Hence care must be taken in design to minimize degradation, both from the standpoint of spectral quality and energy loss (requiring additional heat removal capacity) in the optical system. To obtain a close solar spectrum simulation with any of the lamps discussed previously, filter correction could be incorporated into the optical system to remove unwanted peaks and bands, however, energy loss in the filter, and the resulting heat removal burden, particularly with the Xenon and Mercury-Xenon lamps would represent a large increase in original construction costs, and in operating costs. Figure A-5 shows the spectral calculation for a Xenon lamp, and a Xenon lamp source in an optical system comprising 8 inches of fuzed silica, 8 air-fuzed silica interfaces and 3 reflective components.

As seen in Figure A-4 three functions are performed in the optical system. First, the radiant energy from the lamp is collected; then it is transferred to the collimator assembly; and finally it is collimated. Fuzed quartz or the equivalent should be used for the lenses to minimize loss of the ultraviolet spectral intensity and withstand effects of system heating. The lenses must be gas cooled, and particularly, the first condenser and relay lens must be kept free of dust, otherwise fuzing of foreign matter into the lenses may occur. Special provision must be made for cooling the hyperboloidal reflector. The system shown in Figure A-4 may be classed as on-axis since all units act on a single optical axis. From the figure it can be seen that theoretically there is a dark spot beneath the hyperboloidal mirror. In the illuminated area, the test specimen will see the simulated sun only in those lamp units within the "decollimation" angle of view. In other visible mirrors it will see primarily either its own image, that of the chamber wall or of the chamber floor (neglecting the direct thermal radiation from the component surfaces, i.e. the system "noise"). View of the test specimen of itself or of the chamber floor in the mirrors is undesirable from the standpoint that the space sink view factor is reduced.

The optical system used with the 32 KW, 16 mm carbon arc system more closely resembles motion-picture projector optics than the system shown for the compact arc lamp, however, the functions performed are similar.

With an array of lamps integrated into one system, an off-axis collimation system may be applied. Figure A-6 shows such a configuration. The paraboloidal mirror at the upper most position is formed from four quandrants of a paraboloid, with the central portion deleted, and the inside cupped portions rotated 180° such that they face outward.

Figure A-6 also depicts the off-axis feature, where the axis of collimation from the paraboloidal mirror, forms angles with the axis of transfer from the collector arrays hence, the system is termed "off-axis". The advantage of this system is that the target hyperboloidal mirror is eliminated and the paraboloidal reflectors can be designed such that off the axis of collimation the test specimen can see by reflection only cryopaneled chamber walls, and vision of the floor and its own reflection are precluded.

Moving Sun Concepts

To provide the desired capability for movement of the solar simulating source requires development of systems which are not currently reduced to practice. The following concept, designated the "moving sun" concept, is discussed as a possible solution meeting the stated requirements, insofar as possible within the current state-of-the-art. This concept appears feasible, but will require considerable design development,, which is beyond the scope of this study, before execution in hardware can be undertaken with assurance of success.

This moving sun concept is based on two radiation sources. To simulate the solar spectrum in a 20 foot diameter target area, use of a Xenon 5 KW lamp module is a possible approach. Because this module would be placed in a movable array inside the vacuum environment, to permit movement with minimum chamberwall penetration, a sealed or "canned" configuration is required. Such a "canned" module using a 5 KW Xenon lamp has been proposed for the NASA Space Propulsion Facility, Plumbrook, Ohio, and is shown in Figure A-7.

The Space Propulsion Facility solar simulating module is designed for vertical or horizontal operation. In the moving sun concept, operation in all inclinations from horizontal to vertical would be required. In this moving sun concept and the Space Propulsion Facility concept, Xenon lamps would be used rather than carbon arcs since maintenance of the carbon arc feed system inside a vacuum environment is not considered feasible. Mercury-Xenon lamps would not be used for the moving sun, since these are subject to greater degradation than the Xenon lamp through deposits inside the lamp envelope when operated in other than design orientation.

From the Stefan-Boltzmann radiation law, it is noted that the factors concerned with the quality of the simulated spectrum are the absorptivity to emissivity ratios. Infidelity in the simulated solar spectrum envelope may be equated to a change in the a/e at the wave lengths corresponding to the spectrum deviation, and has a linear effect on radiation propagation. Previously, it was cited that at 300°K the test item temperature changed only 10% for a 50% change in the linear factor of the radiation equation, hence, a reasonable compromise in spectral match may be acceptable in order to achieve a system most compatible with the requirement for simulation of the solar movement apparent at the lunar surface.

The 5 KW Xenon lamp module designed for the NASA Space Propulsion Facility, is based on the experience gathered on design, fabrication and operation of the NASA Goddard Space Flight Center 2 1/2 KW Mercury-Xenon Space Environment Simulator lamp module. However, operating experience has not been developed with the 5 KW Xenon lamp. Novel features of the 5 KW canned module include the provision for removal of heat from the module optical elements. Nitrogen gas is circulated in the module, and passes through a heat exchanger having a 30% methanol water solution circulating on the "cool" side. Hence, cooling is accomplished by means of circulating the methanol-water through the canned modules from outside the space simulation chamber. The design for the currently proposed NASA Space Propulsion Facility provides for fixed inlet and outlet methanol-water feed lines for the canned modules. In the moving sun concept, flexible conduits must be provided, which presents requirements for systems design and development. Figure A-8 demonstrates the manner in which individual canned modules would be assembled into an array.

Based on recommendations made by General Electric Company representatives, to accommodate the wide spectrum of orientations possible in the moving sun concept, particularly if movement in a 180° arc is necessary in the moving sun concept, lamps would be operated at 70 to 80% design rated output to minimize any degradation aggravated by misorientation.

To provide for the 20 foot diameter target, using the de-rated 5 KW lamp module an array pattern of 121 lamps as shown in Figure A-9 would be used. At lamp rated power, 90 modules would provide the desired irradiation, but to allow for operation at 70 to 75% rated power and to provide the optimum configuration to irradiate the circular area, 121 modules would be necessary.

The second radiation source (infrared) to extend the radiation pattern to an area of 20 feet by 49 feet would be essentially a Tungsten-Iodine doped lamp with Quartz envelope, a reflector, and "stove pipe" collimators to minimize slop-over of the individual lamp beams. Use of bare tungsten filaments has been shown impractical in USAF Arnold Engineering Development Center studies. This feature would be somewhat in the advance of the art if large lamp modules are considered. Lamps as large as 5 KW capacity are currently available, and it appears feasible to integrate a 1.0 KW lamp into an array in which about 25% of the lamp input energy is projected as radiation onto the target area. Refinement of this figure would require detailed optical analysis and design which is beyond the scope of this study.

The tungsten lamp in addition to providing the thermal radiation on target will provide for a fair level of visible illumination, making the radiation exposure realistic from the standpoint of the human operator. It may be necessary to provide for cooling in the lamp array to absorb heat from the stove pipe collimators. Quartz envelope lamps operate at higher temperatures than soft or hard glass envelope lamps and hence are more suitable for application in a vacuum environment.

Assuming 1.0 KW thermal lamp modules, directing about 25% of the lamp input energy to the target area, in a fairly uniform 140 watt per square foot pattern, hexagonal stove pipe collimators would be about 0.9 feet across the flat of the hexagonal cross sections. Figure A-10 shows a thermal lamp module arrangement possible for assembly of an array of modules.

One possible variation of the moving sun concept could comprise a moving array of modules located on a two step or cascade of tracks (Figure A-11). The first track assembly mounted in a vertical arc could allow the array to rise and descend along the chamber side and top in an arc of 90° or more, for example, from side "sun" to top "sun" positions. The second set of tracks could be mounted on the first, running horizontally in the chamber, upon which the solar spectrum simulating module array could be mounted, thereby permitting the module to translate its position from one point adjacent to the test specimen axis to another, on a line 49 feet long (i.e. sufficient to irradiate, in 20 foot segments, the lunar roving vehicles.) The vertical tracks could then be placed on a rotating track permitting rotation through 180°. This arrangement would obviate a requirement for a turntable.

The tungsten lamp module could be mounted between the horizontal tracks, enabling coverage of an area of about 20 x 49 feet. The tungsten lamps could be programmed such that the filaments of the lamps immediately to the rear of the solar spectrum simulating array would be cold. Rough collimation of the thermal lamps necessary to minimize "spill over" of the radiant energy would be provided by the "stove pipes" attached to the reflectors.

The weight of the "canned" 5 KW Xenon lamp modules is about 700 pounds, and the weight of the tungsten lamp module would be about 20 pounds, hence the weight of the respective arrays would be 85,000 pounds and 11,000 pounds giving a total of about 96,000 pounds or nearly 50 tons. This weight could be supported between two arch supports allowing the arrays to pass over the target area.

The 5 KW canned solar simulation module (Figure A-7) which is considered for the moving sun concept is essentially the same as that proposed for fixed inside mounting in the NASA Space Propulsion Facility, hence it is not a novel feature of the concepts.

Mounting on a tracking rack is novel (Figure A-11) and requires the development of solutions to several difficult engineering problems.

First, flexible coolant fluid conduits must be provided and a mechanism for free play and slack take-up must be devised. A constant tension saw-tooth take-up section appears to be a possible solution to this problem as shown in Figure A-12. Here the conduit is flaked in a plane parallel to the chamber wall (or tangent plane to the chamber) with peaks of saw-tooth folds held by weighted pulleys or programmed selsyns. Upon playout of the conduit, the saw-tooth form flattens to a single line of conduit at the most extended position. At points intermediate between lamp modules or tee fittings, etc., the coolant conduit must be supported on rollers. Assuming 15 foot "saw-tooth" depth, a fold will accommodate 30 feet of conduit. Three folds will accommodate up to 90 feet, and allowing four feet for the retracted saw-tooth mode of storage, 86 lineal feet of conduit may be retracted in such an arrangement within a plane 4 feet by 15 feet in area. Weighted pulleys are simplified examples of tension keeping devices. In practice, more sophisticated mechanisms such as programmed selsyns may be required to grade tension with playout of conduit.

Other problems include:

a. Power distribution to the moving array.

b. Control circuitry between moving array and external control console.

c. Temperature stresses, and effects on alignment of the array.

d. Drive systems, carrying loads, and safety features in the event of malfunctioning.

e. Means of final alignment of modular units to assure desired beam path.

In addition to the necessity for solving more novel engineering design problems for the moving sun concepts than with the alternate fixed sun concepts considered, a moving sun will require a larger chamber than the fixed sun alternates in order to accommodate the internally located tungsten lamps and the solar spectrum simulating modules. Space will be required for the drive mechanism and tracking systems for the tungsten lamp array. Four feet will be required from the cryopanel wall to accommodate this system. The solar simulating array would be located such that it may pass in front of the tungsten lamp array, and would require an additional eight to ten feet projection in front of the tungsten lamps. Since the length of the overall "thermal" and "solar" radiation pattern is 49 feet, its width 20 feet, taking the array as equivalent to these dimensions in cross section, the volume for accommodation would then be about 49 x 20 x 14 or 13,700 cubic feet. Provision must be made for orienting the modular arrays in the vertical plane, such that at the side sun position, the incoming beam may be adjusted to fall normal to the test specimen vertical surfaces.

Other problems associated with this concept include maintenance of the flexible coolant lines, electrical power and control cables, and many design restraints, such as minimum radii of arc required for flexible conduits in the stored positions (Figure A-12).

In studying systems for consideration as the moving sun concept, (which allows translation of the solar spectrum simulating array along the axis paralleling a deployed ALSS system) it was felt that in the interest of test set-up flexibility, it would be desirable to consider moving the solar spectrum simulating beam along the test specimen deployment axis to expose the components as desired to the "solar" irradiation. Choosing a fixed location could conceivably render it impracticable to expose certain test components while in a deployed configuration. If, however, the translating track is eliminated the moving sun concept would be simplified considerably, since the thermal lamp arrays could be placed abreast, or in a plane in front of the solar spectrum simulating modules. The translation of the solar spectrum simulating module across the thermal radiating array requires the assembly to be constructed in a rectilinear fashion, hence in a circular cross section chamber, considerable floor area must be kept free for positioning of the complete radiating assembly. Fixing the location of the solar spectrum simulating array in the center of the extending thermal radiating lamps would enable conservation of floor area required to clear the low most point of the complete assembly. In addition, the otherwise fixed solar spectrum simulating array could be gimbal mounted, such that greater flexibility could be provided in directing the solar spectrum simulating beam to selected portions of the test specimen.

The weight of the solar spectrum simulating array would be about 50 tons, and this weight would be supported by the span of the horizontal tracks. The load of the arrays, and the horizontal tracks would then be carried by parallel arched structures forming the vertical tracks and supporting the drive mechanisms.

As an alternate to incorporation of a turntable in the chamber design to enable horizontal orientation of test specimen with respect to "solar" radiation, the following feature could be incorporated in the moving sun concept. The vertical arched structure cited above could be mounted on tracks in the floor supported in the chamber floor plane, such that the entire assembly, with supporting arches, could be rotated concentrically through an arc of 180° in the horizontal plane.

It is beyond the scope of this engineering study to determine detail design configurations, however, based on technology under development for the support of fixed arrays of the 5 KW canned modules proposed for the NASA Space Propulsion Facility, it is envisioned that a sufficiencly rigid structure may be integrated into a module array consisting of 121 canned modules to afford satisfactory alignment of all the modules in all arc positions from side sun to top sun. Deflection of the module supports presents a design problem, in that there is little free space between the modules in the assembled array. Deflection of the horizontal beams will require provision to avoid binding on the tracks, however, small deflections of the module as an entity should not be a problem in the test since there will exist freedom in positioning and means of orienting the solar spectrum simulating array. The requirement for free travel of the arrays particularly over the tracks will also present problems in design and fabrication, and hence will add to the facility cost.

Although the moving sun concept is inherently more costly, presents engineering and potential maintenance problems, and does compromise the quality of the simulated solar spectrum it most nearly meets the requirements of the Test Philosophy.

<u>Estimate of Requirements - Arc Lamp System, Moving Sun Concept</u>

This estimate is based on conservative baselines, i.e. derating the lamp output (to 73% at startup) to allow longer life at various orientations, allowance for 11 KW radiant energy falling outside the 20 foot diameter target area, and a value for module efficiency of 12.5%. In addition, energy credit is not taken for overlap of the solar simulating and tungsten lamp array beams.

Based on stated module efficiency for the 2.5 KW Honeywell Module used in the Goddard Space Flight Center solar radiation system, assume 12.5% irradiation efficiency at startup and a voltage adjustment to give 73% rated lamp capacity.

Target area thermal load: $\frac{314 \times 140}{1000} = 44$ KW

Thermal load target area and penumbral area: $44 + 11 = 55$ KW

Electric Power to lamps at startup: $5 \times 121 \times .73$ or $\frac{55}{.125} = 440$ KW

The values which follow represent the thermal load which must be removed from the array of lamp modules. Most of the heat may be removed from the modules at or about temperatures of 0° to 20° C by circulating coolants so that the cryosystem burden may be minimized.

At Startup: $440 \times 0.875 = 385$ KW

As the system degrades the lamp operating voltage must be increased to maintain the solar constant and the thermal load could ultimately reach:

$(5 \times 121) - 55 = 550$ KW

Estimate of Requirements - Tungsten Lamp System, Moving Sun Concept

Total area to be covered: $49 \times 20 = 980$ square feet (assuming translation of solar spectrum simulating array)

Area to be illuminated instantaneously: $29 \times 20 = 580$ square feet

Target area thermal load: $\frac{580 \times 140}{1000} = 82$ KW

Assuming 25% efficiency, power required: $\frac{82}{0.25} = 328$ KW

Total Number of lamps illuminated: $\frac{328}{1.0} = 328$

Total number of lamps required in array: $\frac{980 \times 140}{1.00 \times 1000 \times 0.25} = 550$

(assuming translation of the solar spectrum simulating array)

Area covered by individual lamp modules: $\frac{980}{550} = 1.775$ sq feet

Alternate Concepts for Solar Radiation

In view of the complexities inherent in the execution of any of the moving sun concept designs, and to compare the costs, consideration is made also of possible alternates to the "moving sun". The most straight forward approach appears to be the selection of three fixed "solar" positions. In view of all compromises required in attempts to simulate the lunar environment, the compromise of the "quantum jumps" from sunrise to high noon does not appear to cause critical deviation from the Test Philosophy. Effect of heating will, for example, vary as the cosine of the incident angle. With three positions, 0°, 45°, and 90°, the greatest "off angle" of incidence to a surface normal to the desired solar azimuth would be 22.5°, and the difference between cosine of 0° and cosine 22.5° is (1.000-0.924)/1.000 or 7.6%. For surfaces nearly parallel to the solar azimuth being simulated, the difference, of course, would be greater. However, it appears that consideration should be given to the cost-trade-off for a "moving sun" concept against a three position fixed sun.

Alternate Concept 1 is an alternate to the "moving sun" concepts which incorporates carbon arc lamps of the same general type as the NASA Manned Spacecraft Center, Chamber A and MARK I modules. Thirty-one modules of about 32 KW rated input should provide a 20 foot diameter area of irradiation, arranged in a pattern as shown in Figure A-13. For the rising and setting of the sun, in this concept, positions will be limited to the three positions: overhead sun, mid-elevation sun and side sun. This will require triplicate arrays of modules, which may be mounted in the chamber walls such that the lamp maintenance may be accomplished outside of the vacuum environment.

The module in this alternate concept would be essentially the same 32 KW unit proposed for the MARK I space simulator, except for possible upgrading of the unit to provide slightly more than 10 square feet area coverage at 1510 watts per square meter. This upgrading might prove unnecessary if the units now being evaluated prove capable of meeting this performance. In Figure A-13 it is shown that use of 31 modules approximates a pattern giving circular symmetry. In view of the above, use of this module involves no apparent novel features, except for a possible requirement for adjustments for operation at an angle of 45° from the horizontal in lieu of either vertical or horizontal. The greatest part of the heat load of this module would be dissipated outside the space chamber.

Approximately 40 KW may be liberated in the optical condensing system inside the chamber, and 44 KW will comprise the heat load from the irradiated area. The remaining load of about 920 KW would be dissipated by the cooling system components located externally.

In this alternate concept, spectrally simulated solar radiation could be augmented by tungsten filaments lamps either in the same manner as proposed in the moving sun concept, or by use of three arrays of tungsten lamps in fixed positions, corresponding to the elevation angles of the three solar spectrum simulating arrays.

Use of carbon arc lamps will require periodic electrode reloading and provision for exhaust of the electrode combustion products which must be considered in comparison with other concepts. Mounting of the arrays in the chamber walls presents no novel problems, since this mounting is being accomplished in the Manned Spacecraft Center, Chamber A. The use of a movable cryopanels, in connection with a fixed infrared lamp system would present flexible cryoline design and maintenance problems which may result in novel applications. It must be noted, however, that an arrangement such as this concept will be rather inflexible, that is the spot location of the simulated solar beam will be fixed, and cannot be moved to expose flight vehicle, or the Lunar Roving Vehicle during a given test exposure. Movement of the test specimens will be required to afford successive component exposures to the simulated solar spectrum.

Estimate of Requirements for Solar Spectrum Simulating Array, Alternate Concept 1

Electric Power 1000 KW (Based on 32 KW modules irradiating hexagonal areas 40" across flats of hexagon, i.e. approximately 10 square feet.)

Handling of thermal load in optics, inside chamber, approximately 40 KW

Handling of thermal load on irradiated area 44 KW (i.e. approximately 84 KW cryopanel load)

Requirements for the thermal array will be the same as cited in the discussion of the moving sun array.

Alternate concept 2 is a modular system based on a 5 KW Mercury-Xenon compact arc lamp as the solar simulating source. In this concept an array of 91 modules is proposed which would be a development from the 2 1/2 KW Mercury-Xenon modules used in the Goddard Space Flight Center space simulator. In this concept, simulation of three solar positions is proposed, as in the alternate concept 1. Since fixed positions are proposed in this concept modules may be designed for the Mercury-Xenon lamp.

The maintenance problems with the Mercury-Xenon lamp differ from those of the carbon arc lamps of the alternate concept 1. The Mercury-Xenon lamps require simpler support equipment and there are no combustion products to dispose of, and no reloading requirements. Degradation in use does not appear unacceptable, since output may be maintained by increasing lamp current as efficiency degrades. There is, however, hazard in handling the lamps, because of the internal gas pressure, and some breakage may be expected. Also, in the event of lamp breakage, Mercury released presents a health hazard.

Estimate of Requirements for the Solar Spectrum Simulating Array, Alternate Concept 2

Electric Power 440 KW

Handling of thermal load, essentially equivalent to alternate concept 1. In alternate concept 2, thermal supplementary irradiation may be provided in the same manner as for alternate concept 1.

Other Approaches

The above proposed concepts are based on systems currently in design development or actual execution in operating systems, and for which principal components are available. Other approaches include the use of a long arc lamp as shown in Figure A-14. This system would provide poor collimation, and would place a severe burden on heat removal, since the exposed lamps and optics would require all heat removal at the cryopanel temperature.

To meet the collimation requirements, present practice indicates the necessity of applying carefully aligned optics. Mating of existing lamps and modular optics, or use of the integrated carbon arc and optical module being fabricated for the Manned Spacecraft Center, Chamber A, appear to be the most satisfactory approach to this design problem. Performance of the Goddard Space Flight Center solar simulation system demonstrates the general feasibility of the "modular" approach for design of satisfactory irradiating systems. Insofar as modular design is concerned, both the carbon electrode, and compact arc lamp modules are suitable for integrating into modular systems.

Off-axis systems have also been used, and the experience of the General Electric Company has demonstrated the feasibility of this system for top "sun". The application of such a system to provide three solar positions does not, however, appear currently feasible from the standpoint of the geometrical arrangement required for all the necessary components in providing a multiple positioned solar simulating array. The modular unit design appears to present fewer problems in spacing cryopanels, diffusion pumps, and in connections to the chamber interior.

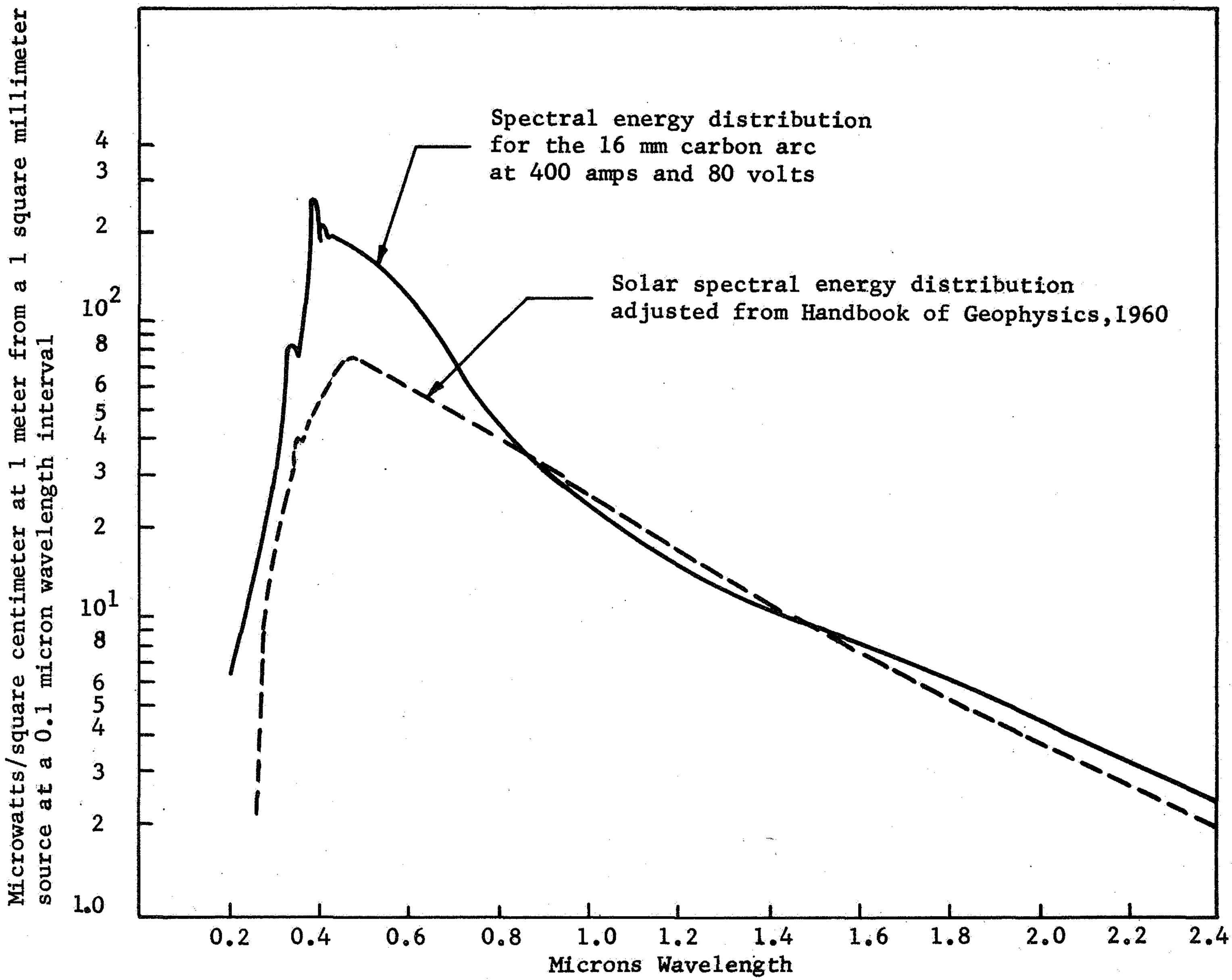


FIGURE A-1 COMPARISON OF A 16 mm CARBON ARC SPECTRUM WITH ADJUSTED SOLAR SPECTRUM ZERO AIR MASS (Adjustment Factor 3.4 x 10^{-3})prepared by National Carbon Corporation

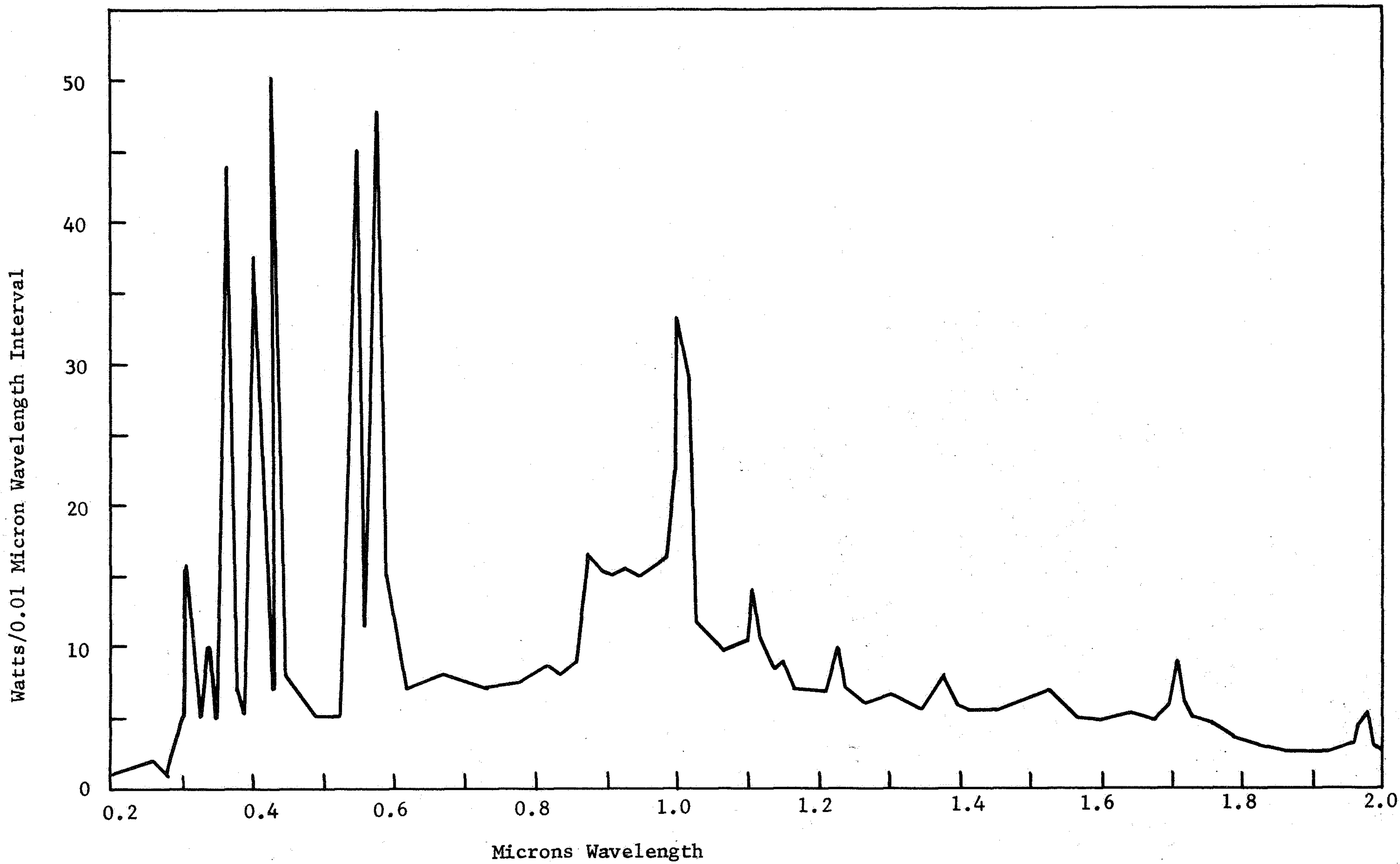


Figure A-2 SPECTRAL ENERGY DISTRIBUTION OF 2.5 KW MERCURY XENON SHORT-ARC LAMP (Westinghouse SAHX-2500 B) TOTAL WATTS RADIATED PER 100 ANGSTROM UNITS WAVELENGTH INTERVAL.

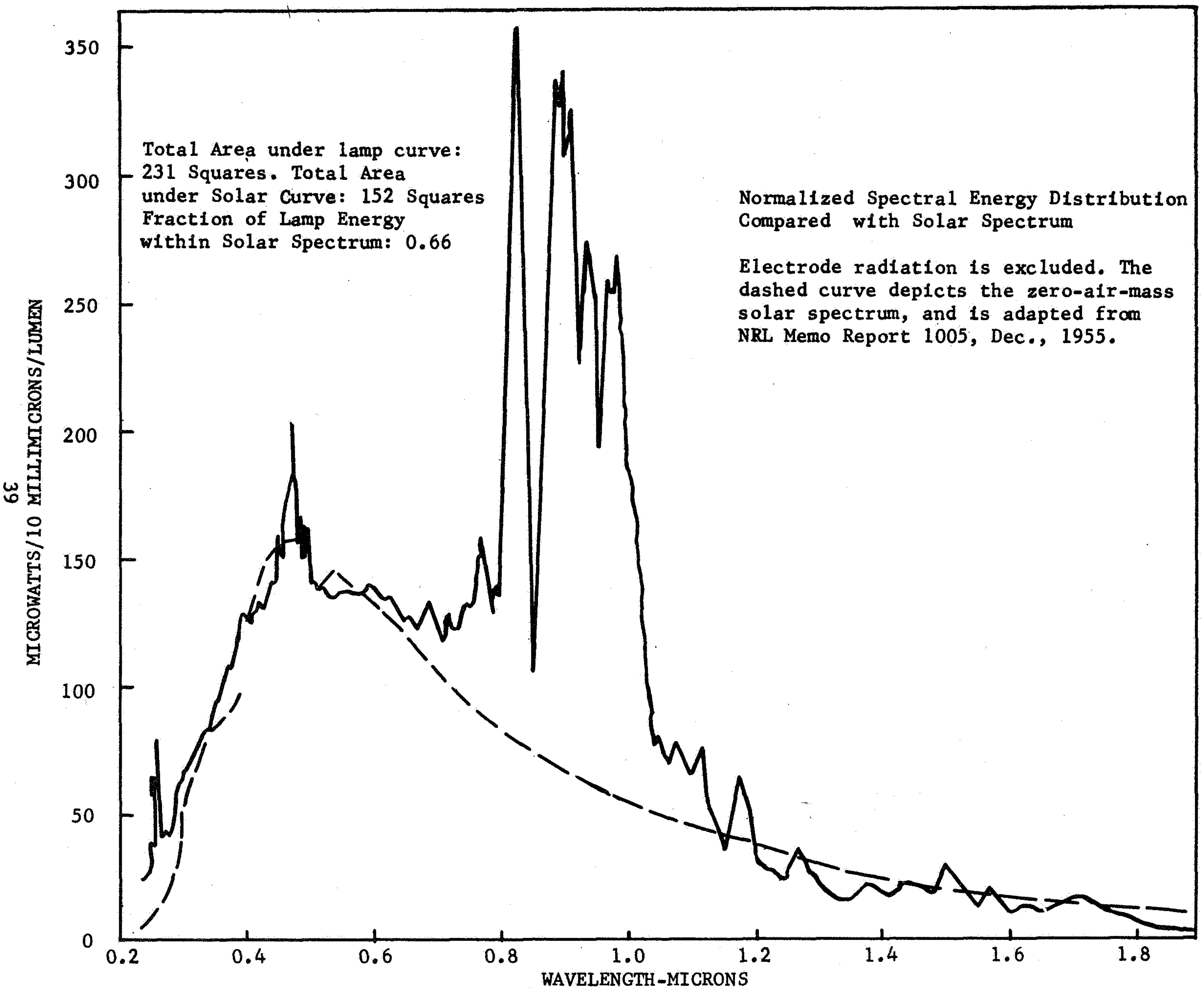


FIGURE A-3 5 KW XENON COMPACT ARC

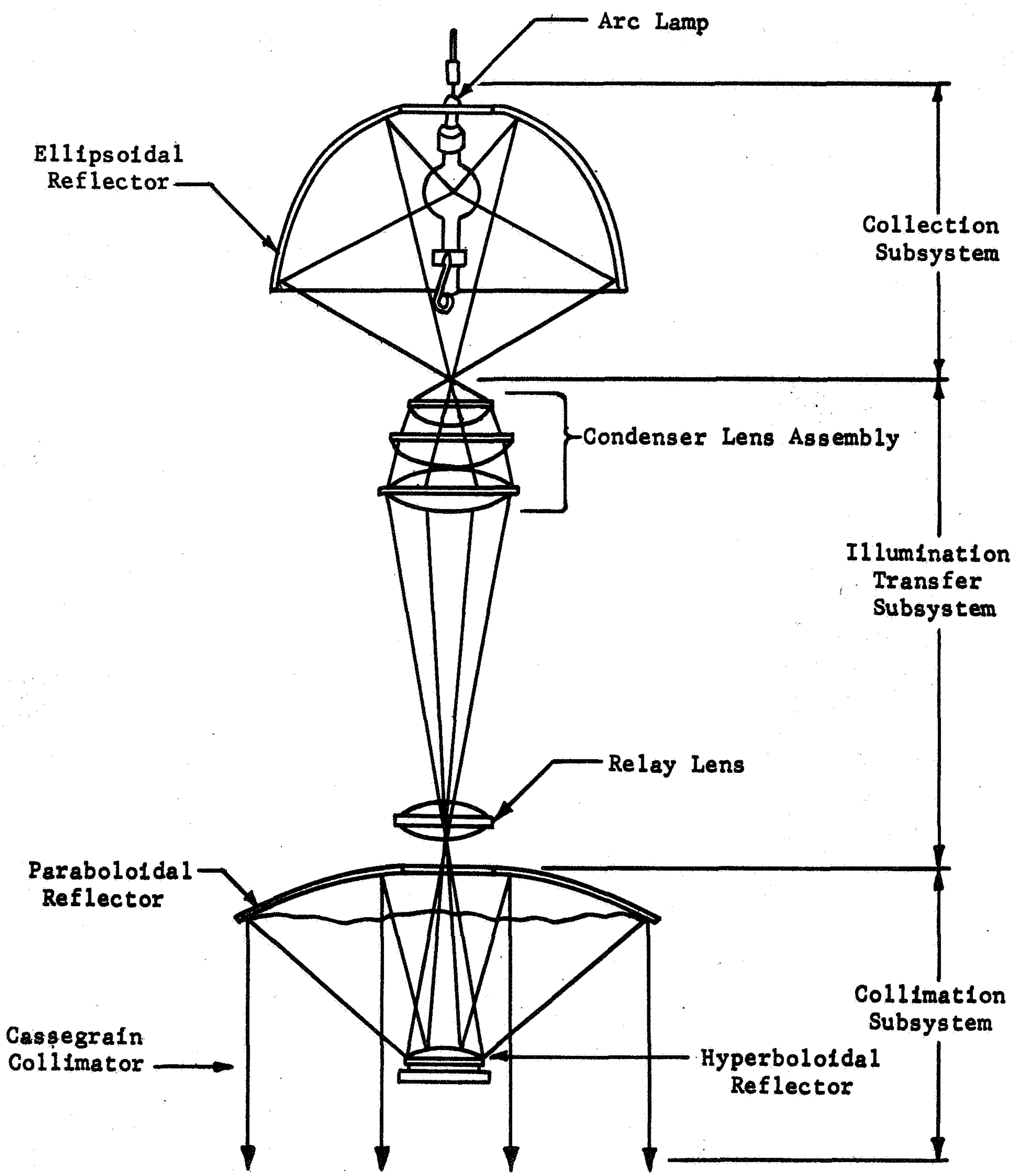


FIGURE A-4 SCHEMATIC REPRESENTATION OF COMPACT ARC SOLAR RADIATION SIMULATOR OPTICAL SYSTEM

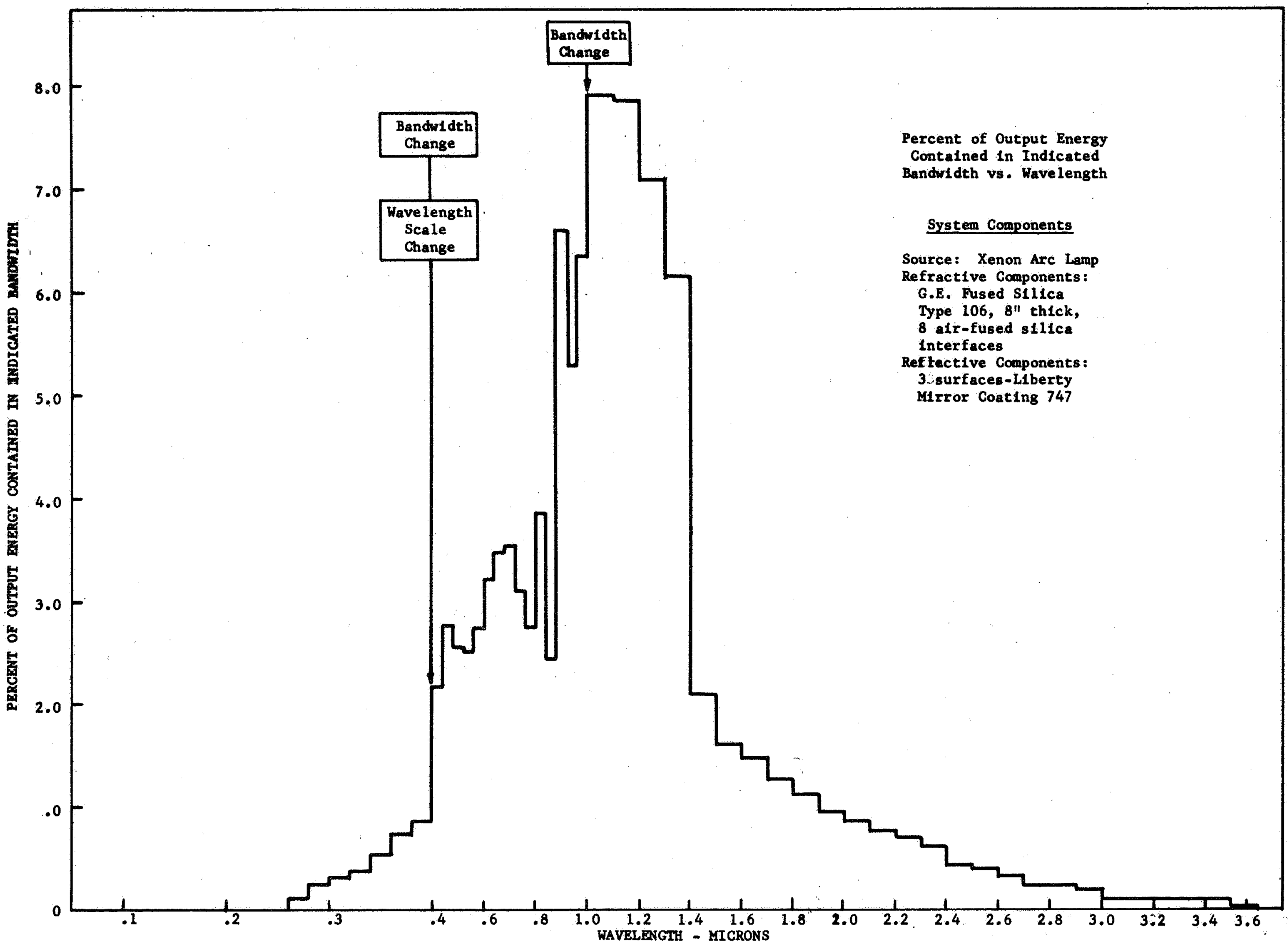


FIGURE A-5 5 KW Xe COMPACT ARC MODULE SPECTRUM

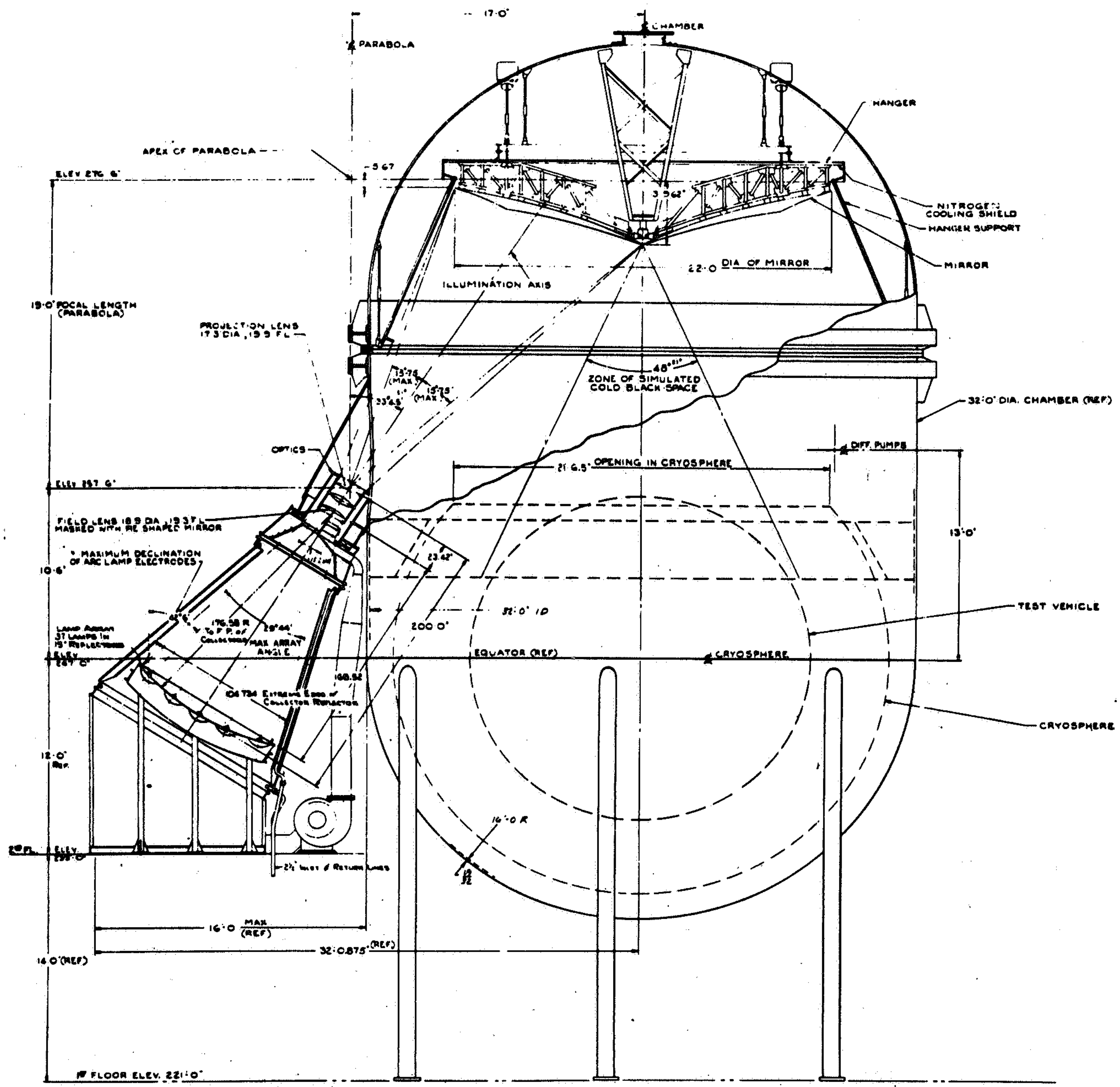


FIGURE A-6 OFF-AXIS COLLIMATION SYSTEM
FOR SOLAR IRRADIATION SIMULATION

Space Environment Simulator
General Electric Company
Valley Forge, Pennsylvania

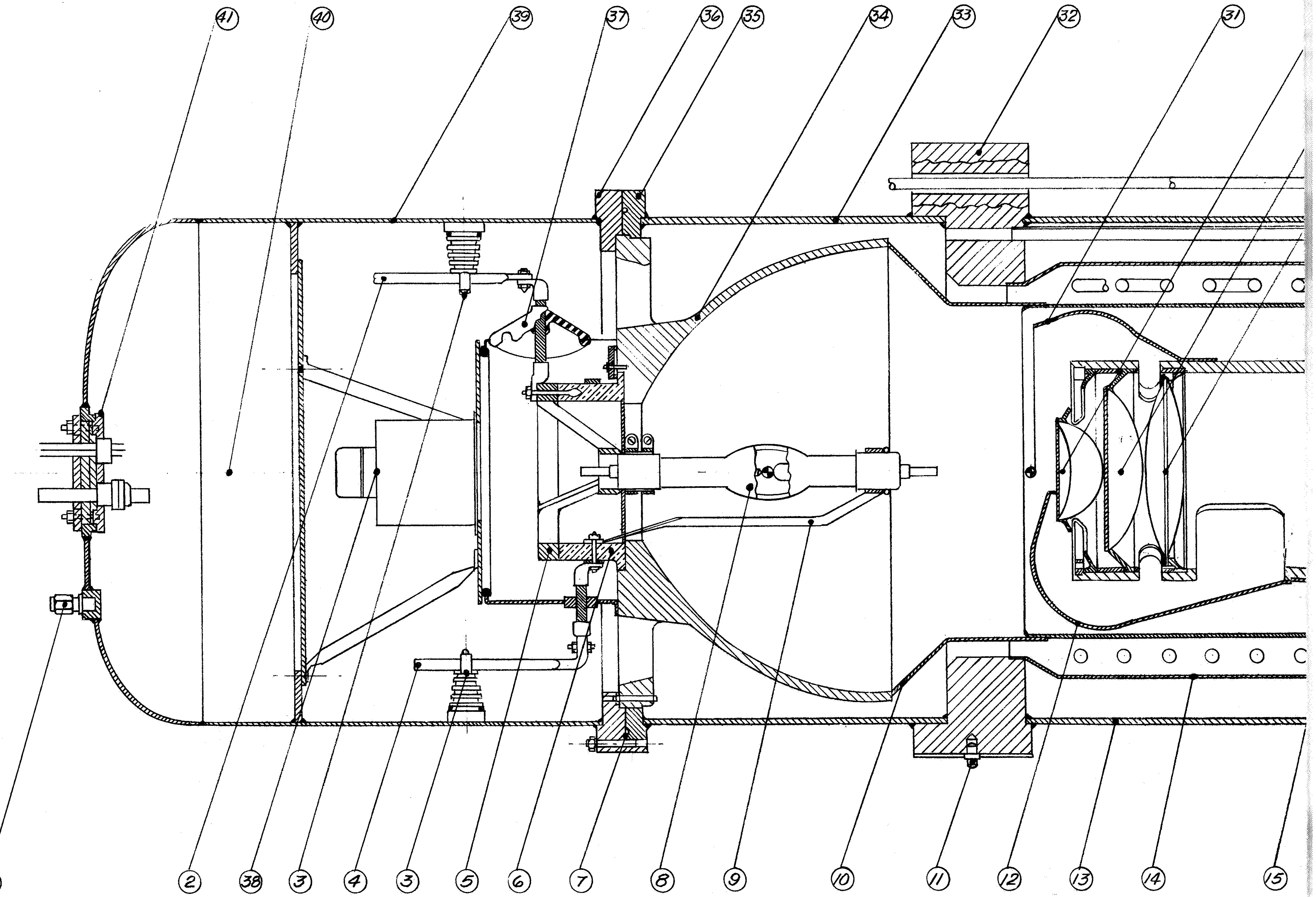
FOLD-OUT #3

Reproduced from "Engineering Study for Solar Simulator Space Propulsion Facility", Prepared by: Honeywell, Inc. Contract No. NASA - 5024.

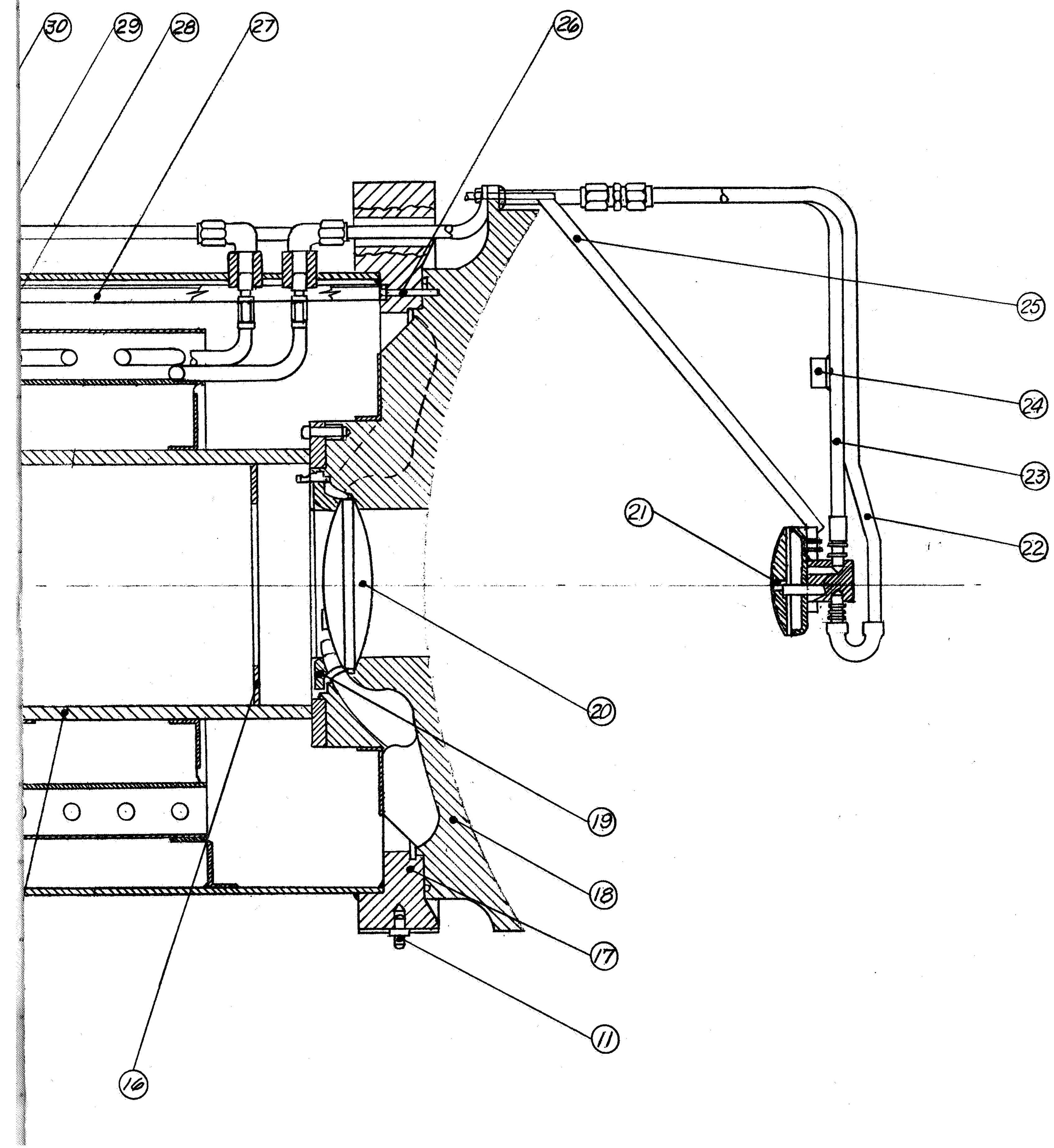
1	EVACUATION PORT	21	HYPERBOLOIDAL REFLECTOR
2	CATHODE LEAD TO LAMP	22	COOLANT TUBE (OUTLET)
3	CERAMIC STAND OFFS	23	COOLANT TUBE (INLET)
4	ANODE LEAD TO LAMP	24	INTENSITY SENSOR
5	LAMP MOUNT AND CATHODE CONNECTION	25	HYPERBOLA SUPPORT BAR (3)
6	LAMP MOUNTING RING (CERAMIC)	26	PARABOLA MOUNTING BOLT
7	VITON "A" O-RING	27	PARABOLA MOUNTING BOLT ACCESS TUBE
8	LAMP	28	LENS #3
9	ANODE LEAD (3)	29	LENS #2
10	ELLIPSE EXIT SHROUD	30	LENS #1
11	ALIGNMENT PIN (2)	31	GN_2 SHROUD (CONDENSER EXIT)
12	GN_2 SHROUD (CONDENSER ENTRANCE)	32	MODULE SUPPORT FLANGE
13	PRESSURE SHELL LENS SEGMENT	33	PRESSURE SHELL ELLIPSE SEGMENT
14	HEAT EXCHANGER	34	ELLIPSOIDAL REFLECTOR
15	CONDENSER LENS MOUNTING TUBE	35	PRESSURE SHELL END FLANGE
16	MECHANICAL APERTURE (RELAY LENS)	36	UTILITY END DOME MOUNTING FLANGE
17	PARABOLA MOUNTING FLANGE	37	CATHODE LEAD BOOT (SILICONE RUBBER)
18	PARABOLOIDAL REFLECTOR	38	AXIAL FLOW FAN (GN_2 SYSTEM)
19	RELAY LENS MOUNTING RING	39	UTILITY END DOME
20	LENS #4 (RELAY)	40	IGNITER PACKAGE
		41	FEED-THRU FLANGE

FIGURE A-7 5 KW XE SEALED ENVIRONMENT LAMP MODULE

FOLD-OUT #1



FOLD-OUT #2



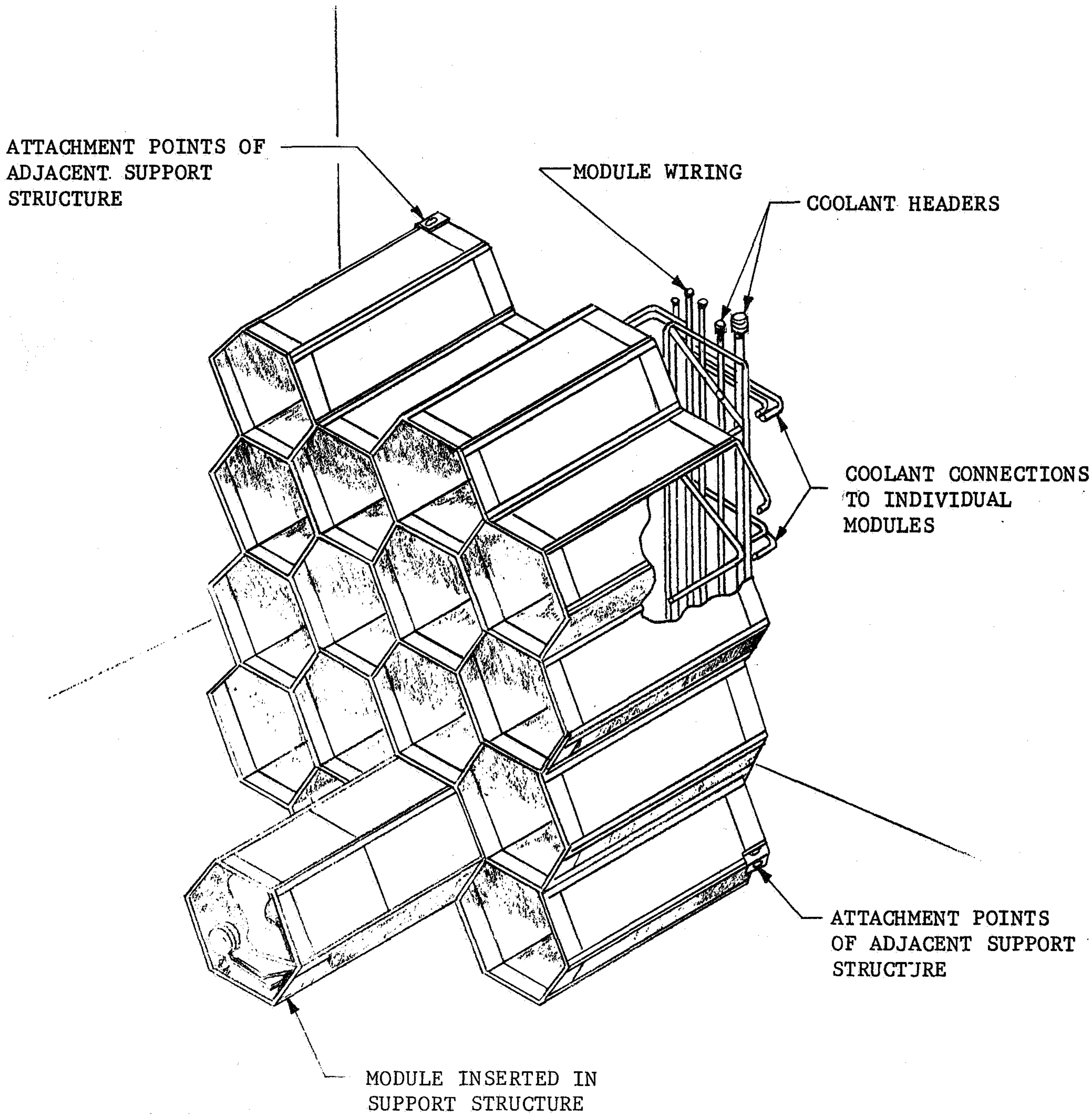


FIGURE A-8 , 5 KW Xe LAMP SEALED MODULE ARRAY ASSEMBLY

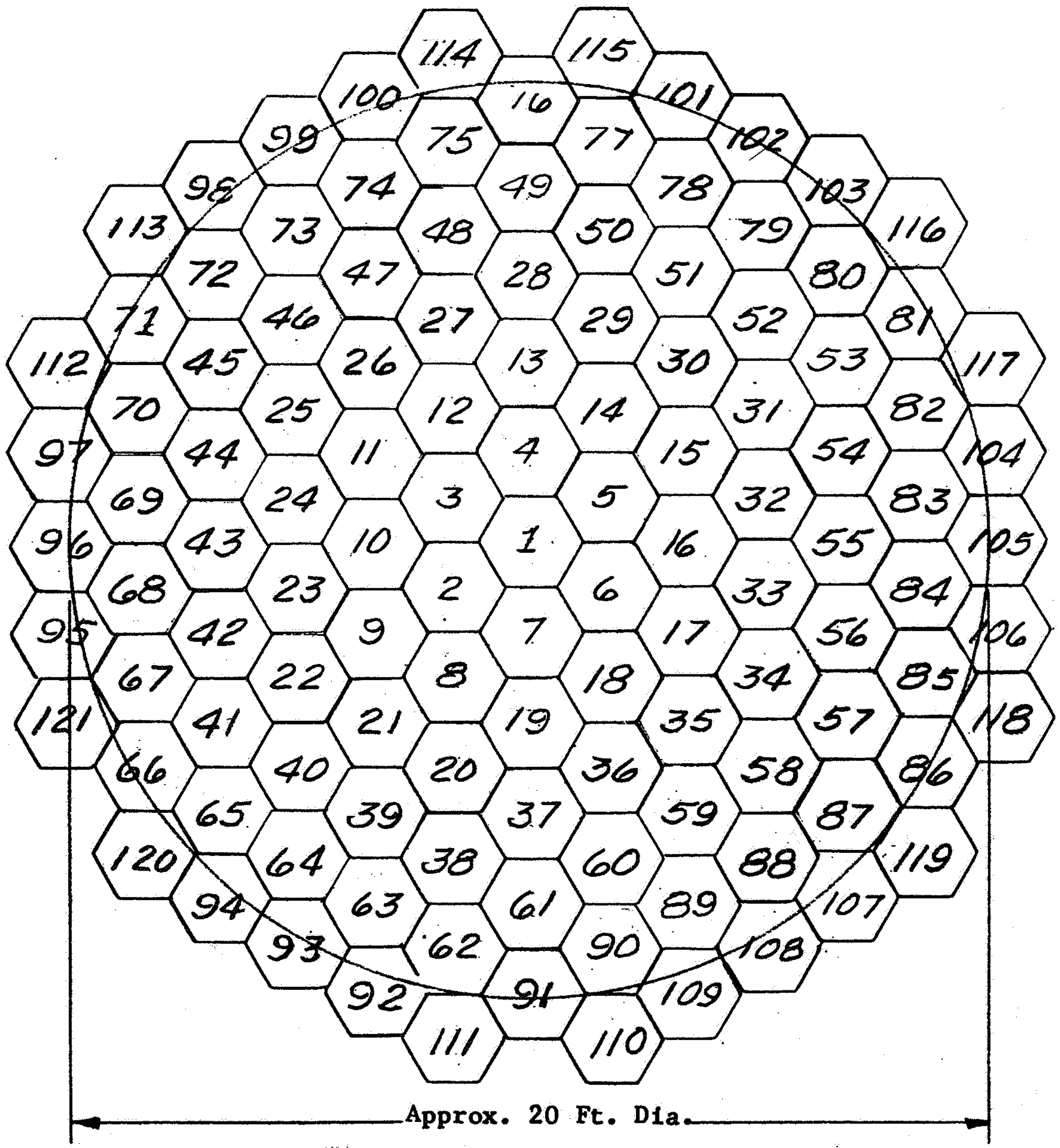


FIGURE A-9 SCHEMATIC 121 MODULE ARRAY FOR APPROXIMATE 20 FT. DIAMETER BEAM USING 5 KW Xe LAMP SEALED MODULES

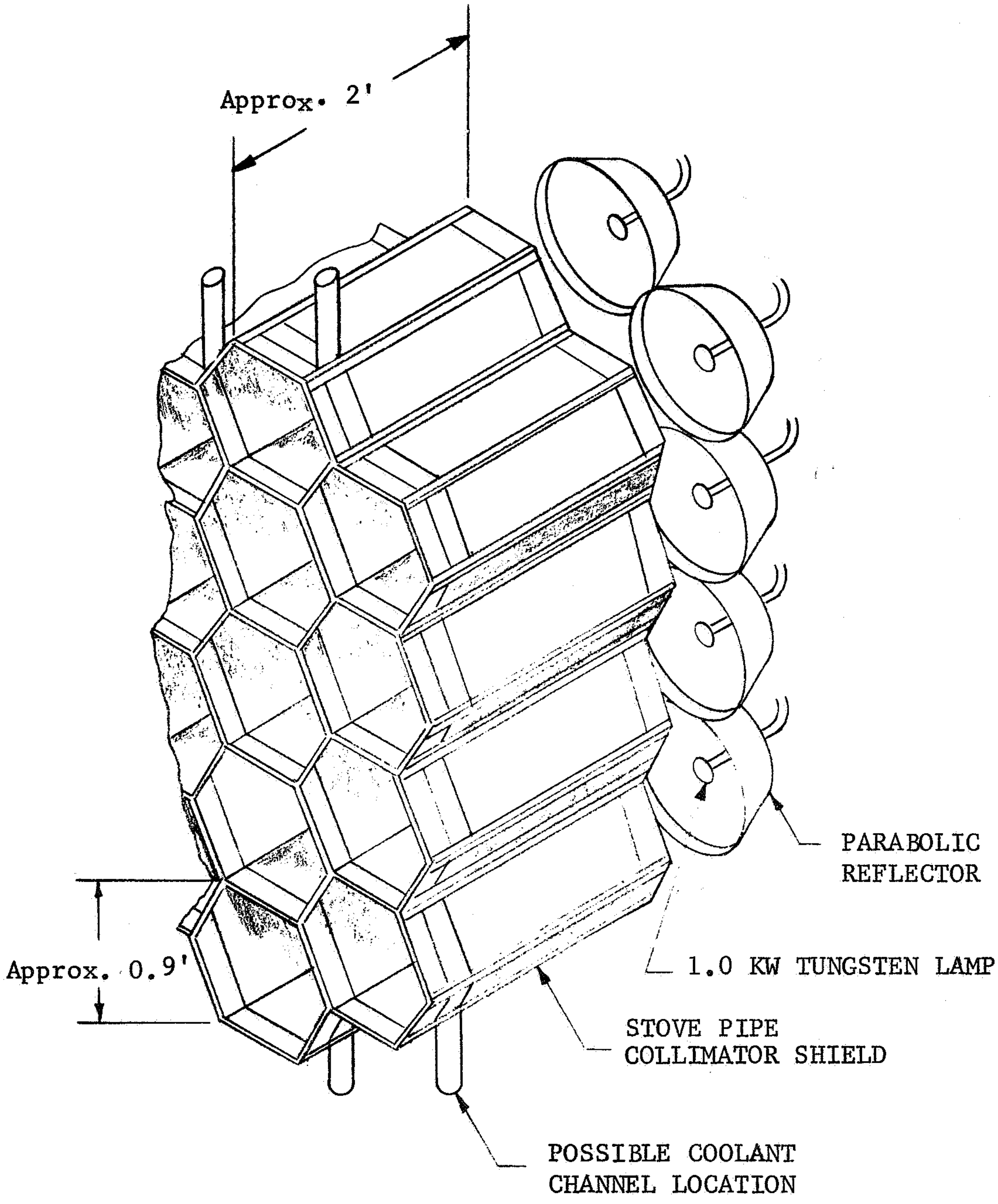


FIGURE A-10 TUNGSTEN LAMP ARRAY ASSEMBLY,
1.0 KW LAMP MODULE

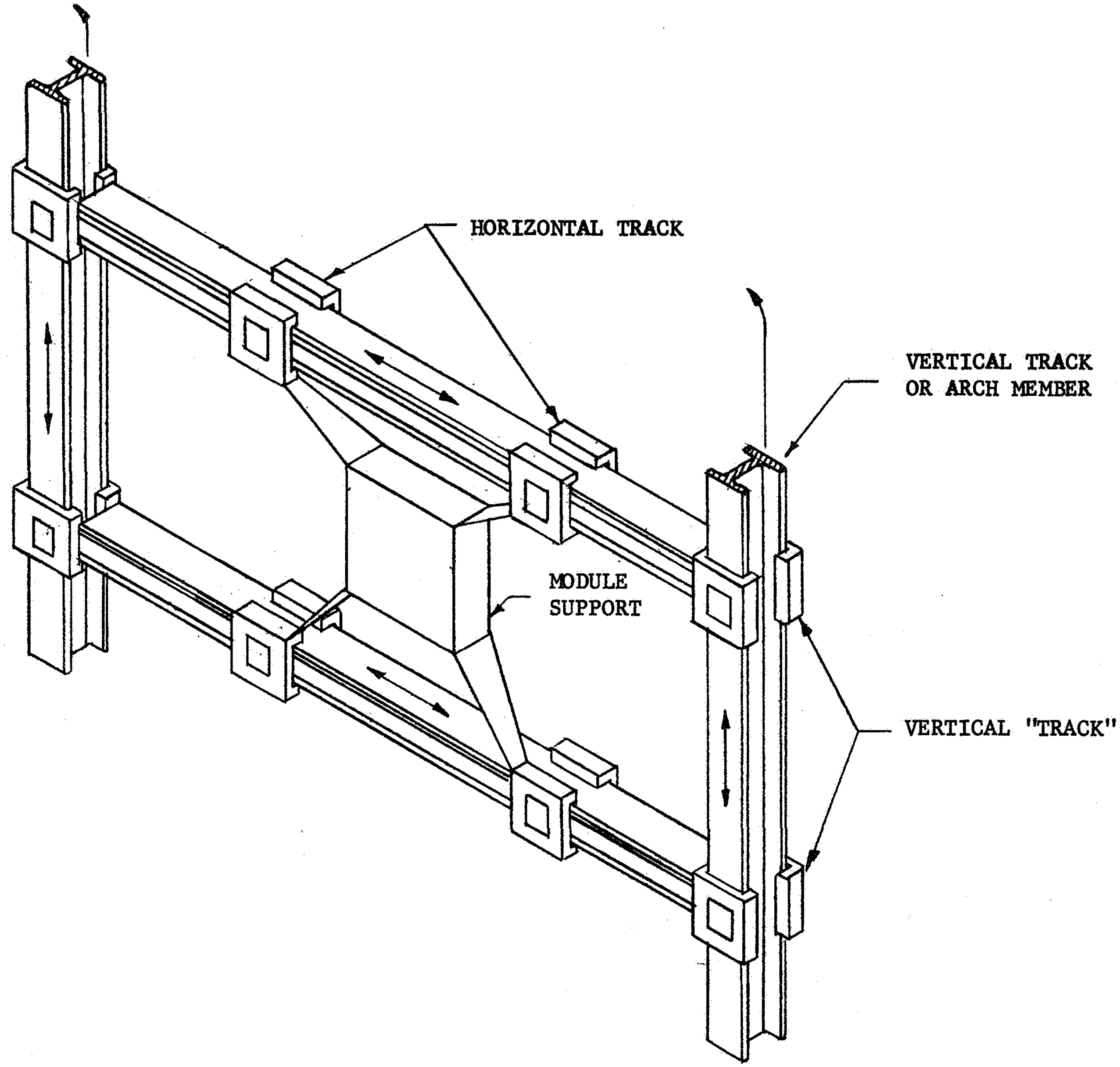


FIGURE A-11 SCHEMATIC SHOWING PRINCIPLE OF DOUBLE TRACK ASSEMBLY FOR MOVING SUN CONCEPT

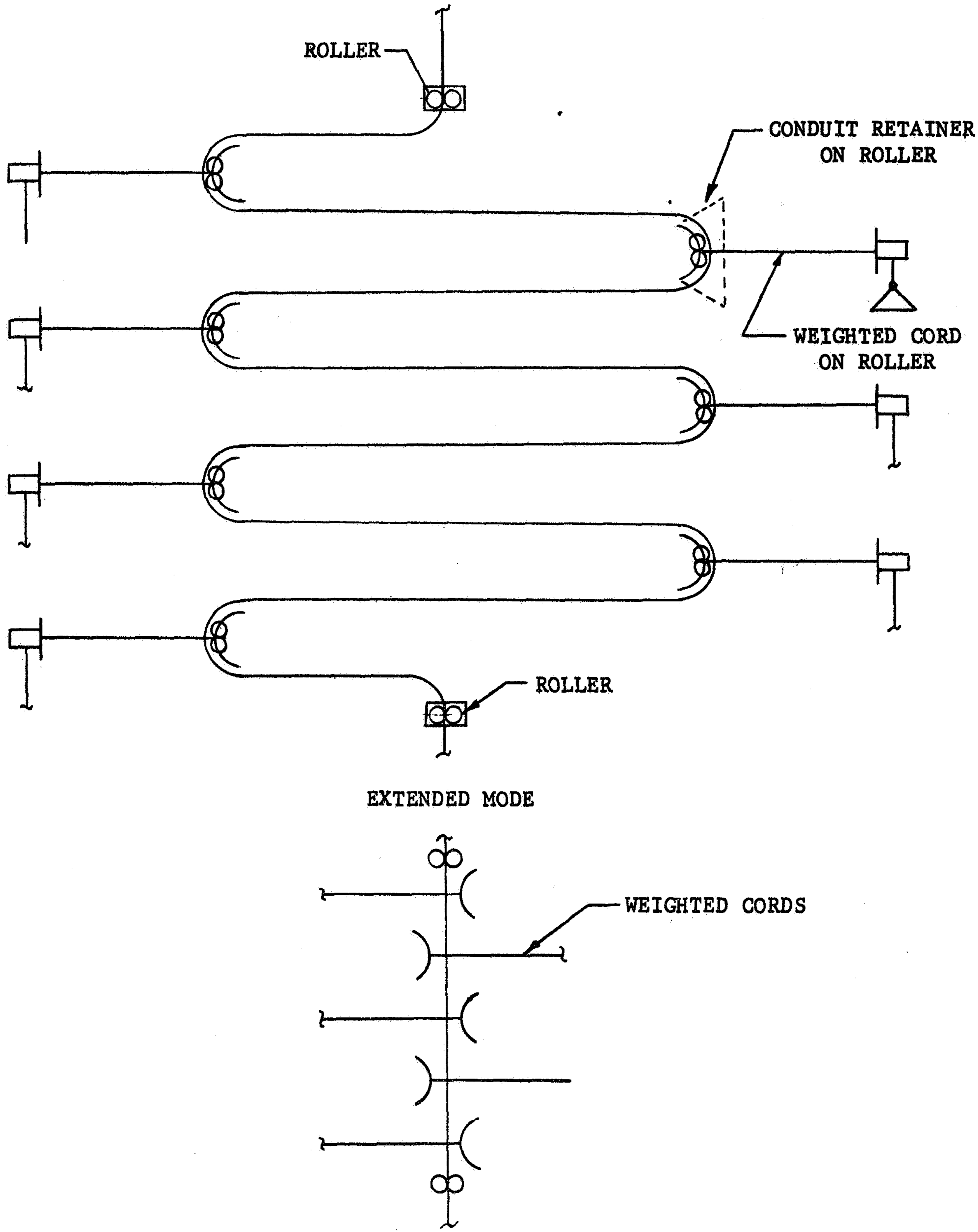


FIGURE A-12 CONDUIT STORAGE, CONTRACTED MODE

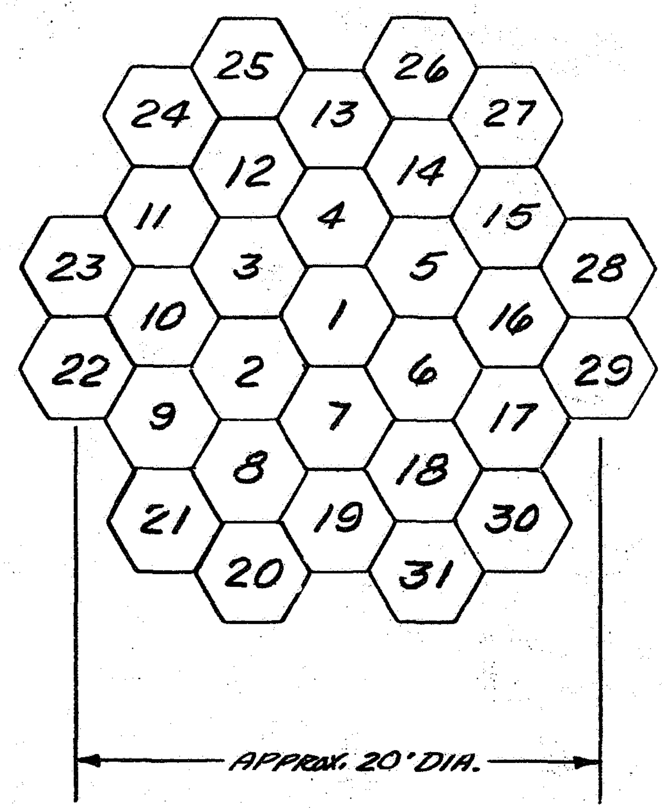
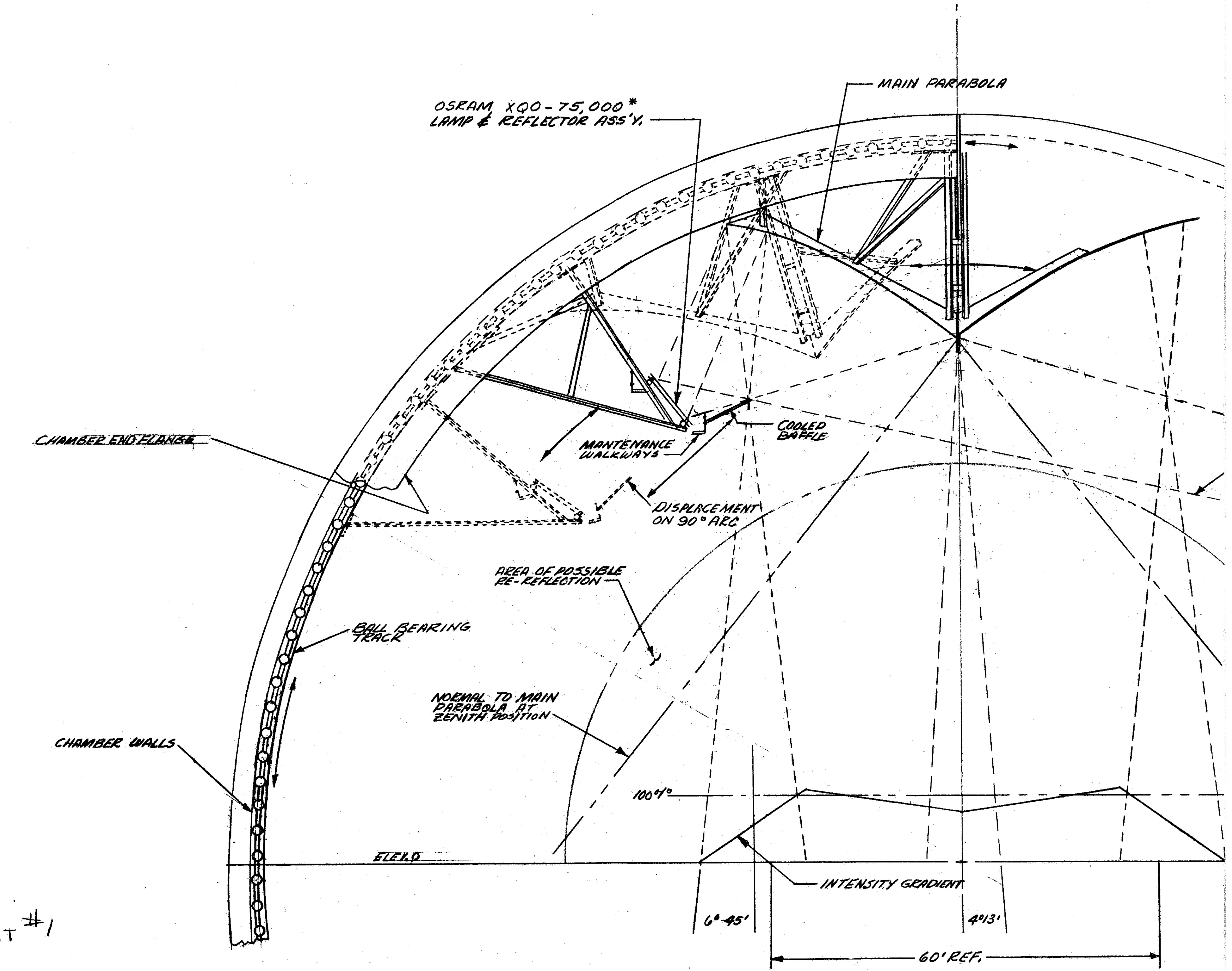
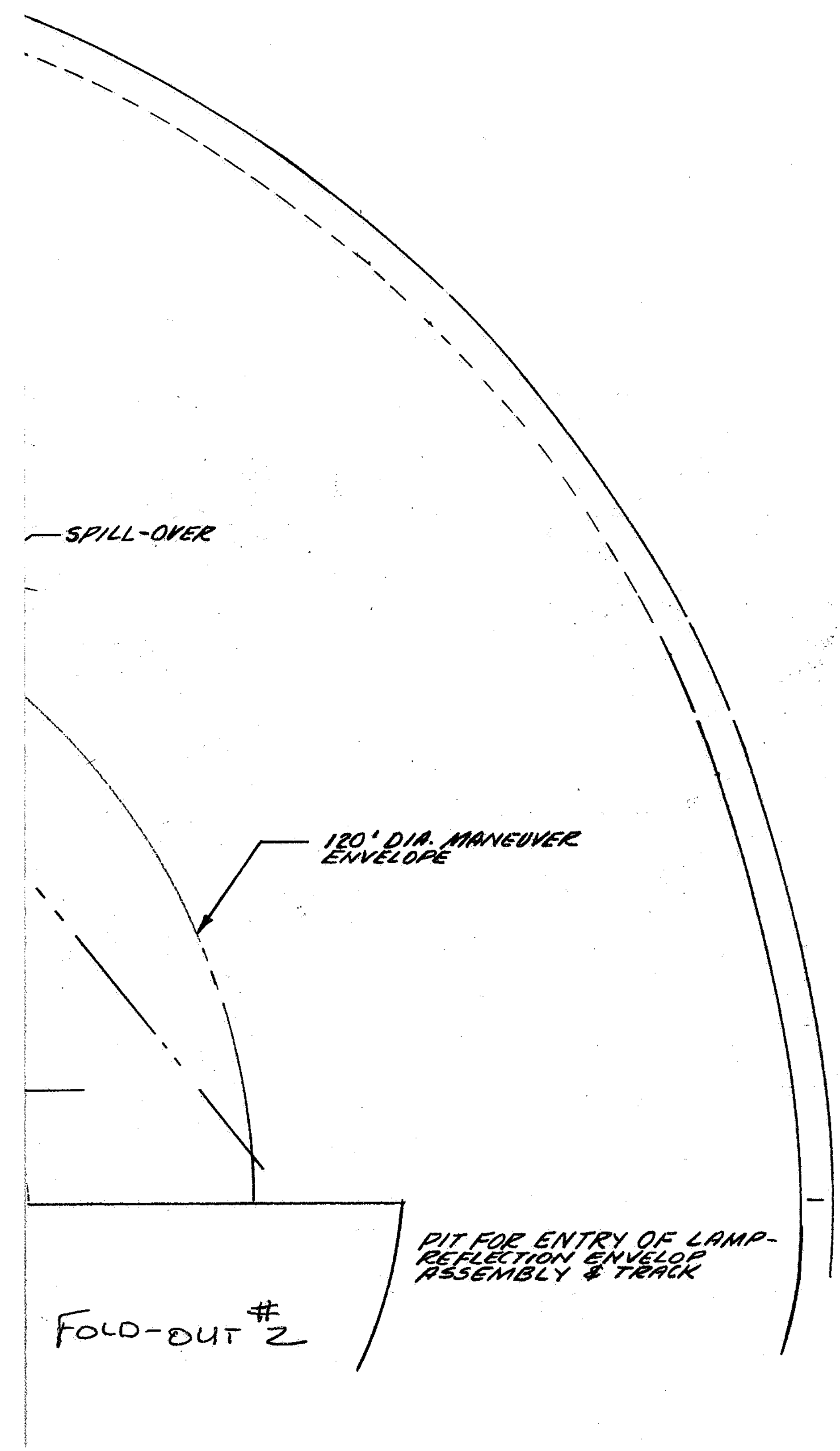


FIGURE A-13 SCHEMATIC 31 MODULE ARRAY FOR APPROXIMATE 20' DIAMETER BEAM USING 32 KW CARBON ARC LAMP MODULES


MAIN PARABOLA
OSRAM XQO-75,000*
LAMP & REFLECTOR ASS'Y.
CHAMBER END FLANGE
MAINTENANCE
WALKWAYS
COOLED
BAFFLE
DISPLACEMENT
ON 90° ARC
AREA OF POSSIBLE
RE-REFLECTION
BALL BEARING
TRACK
NORMAL TO MAIN
PARABOLA AT
ZENITH POSITION
CHAMBER WALLS
100%
EL. 0
INTENSITY GRADIENT
6°45'
4°13'
60' REF.

FOLD-OUT #1



* XENON LAMP 220 cm X 55mm DIA.
McBETH SALES CORP., NEWBURGH, N.Y.

FIGURE A-14
EXAMPLE OF A NOVEL
LUNAR DIURNAL CYCLE
SIMULATOR SYSTEM
USING OSRAM XQO-75,000 TYPE
TUBULAR SOURCE SIMULATOR

J.B.P. 7-27-64

B. EARTH SHINE

Test Philosophy Requirements

The Test Philosophy, Appendix B, sets forth the requirement for earth shine simulation, including the desirability for simulating the relative moon-earth movement.

Characteristics of Earth Shine

Earth shine on the lunar surface is estimated to range from 10 to 17.5 lumens per square meter. This is equivalent to 0.015 to 0.026 watts per square meter visible radiation at the lunar surface, at essentially solar illumination "efficiency". For comparison, total solar radiation to be simulated is 1510 watts per square meter. However, the correlation of lumens to watts total radiation is a function of the conversion system. For example a candle produces about 0.1 lumen per watt, a tungsten filament from 10 to 35 lumens per watt input.

Methods of Simulation

Assuming a lamp module collection efficiency of 25%, then at 10 lumens per watt, $(17.5)/(0.25) \times (10) = 7.0$ watts per square meter are required for earth shine, hence on each thermal module an auxiliary pilot lamp and suitable voltage control may be included to accommodate earth shine requirements. Another method to provide earth shine would be operation of the infrared irradiating array at an extremely low voltage. In the description of the infrared array, it was proposed that this be composed of unfiltered tungsten lamps to provide visible illumination of the order of magnitude present in solar radiation at the moon's surface. The Test Philosophy does not state spectral requirements for earth shine, however, low temperature operation of tungsten filaments would produce infrared and red rich radiant energy spectra. Because of this characteristic of operation at the extremely low level of illumination, it appears more convenient to use supplementary tungsten lamps in the infrared array and solar simulating modules to provide the earth shine simulation.

Unless the simulated earth shine is collimated, the relative position of the earth and moon in simulating earth shine does not appear to influence the simulated conditions; however, use of supplementary lamps in the tungsten filament lamp array will enable positioning of the apparent source of earth shine, or three fixed arrays as proposed for alternate concepts 1 and 2, would allow three positions. Additionally, since these tungsten filament lamps should provide essentially spot type beams an approximate degree of collimation may be achievable for both the thermal "infrared" and radiation earth shine using the same basic array for both types of radiation, as proposed above.

C. LUNAR SOIL SIMULANT

Test Philosophy Requirements

For Combined and Major Systems Testing, a thin layer of soil simulant is required for thermal balance simulation. The prime consideration being the simulation of the a/e ratio. For subsystem testing, realistic simulation of lunar soil reaction is desired. This simulation would require greater soil depths.

Characteristics of Soil Simulants

Characteristics of soil simulants are divisible into two categories; one thermal and the other mechanical. The thermal category of characteristics includes:

Absorptivity of solar radiation (a)

Emissivity of thermal radiation (e)

The ratio of absorptivity to emissivity (a/e)

Heat capacity (c)

Thermal conductivity (k)

Thermal stability

The mechanical characteristics include:

Overall density

Particle density

Bearing pressure

Gas absorptivity - desorptivity or outgassing rate

Resistance effect on rolling devices, etc.

While only a "soil-like" material can reasonably serve as a soil simulant, the characteristic criteria can only be derived secondarily from visible and radiometric observations of the lunar surface.

To meet the Test Philosophy test requirement for Major and Combined Systems tests, a surface coating should suffice to simulate the desired a/e ratio. For subsystem test and evaluation, thickness of the soil layer must be considered. In such a test program no excavation or subsurface construction is contemplated. Therefore, only the active effects of the soil layer on vehicles or men traversing its surface need be considered. These effects are its a/e ratio, thermal conductivity, bearing capacity and its physical restraining effects on wheel movement. The first two named properties can be successfully simulated with a minimum soil depth, say 3 to 6 inches. The second two, bearing capacity and physical restraining effects (as concerns the proposed simulant, a cohesionless, dry, sand-sized soil) can be approached through a factor of sinkage in response to proposed wheel loading.

Proposed loadings for environmental testing vary between 900 and 4000 earth pounds per wheel. If these loadings are represented as a one-square-foot footing on top of a five foot depth of soil simulant, the effective pressure bulb at five feet depth (static) would be approximately 300 pounds for 900 pound surface loading and approximately 1400 pounds for 4000 pound surface loading. (See Figure C-1) Thus a ten foot thick soil layer would be necessary to have zero pressure on the artificial sub-stratum. However, field tests on dry sand within the range of footing pressure indicated (900-4000 pounds) have resulted in a total sinkage of zero to 2 inches, suggesting that a much shallower depth such as 3 feet might be acceptable. This depth would also meet the essential requirements for a temperature gradient in the simulated lunar soil as suggested in Figure C-2.

Currently there exists no soil simulant meeting all desired characteristics, hence development studies will be necessary to provide such a simulant.

In development of a lunar soil simulant, it must be realized that some compromise of characteristics may be required from the standpoint of simulant cost and facility in meeting criteria such as the desired maximum outgassing rate. The criticality of the mission must be held as a guide in determining the extent to which criteria are to be met.

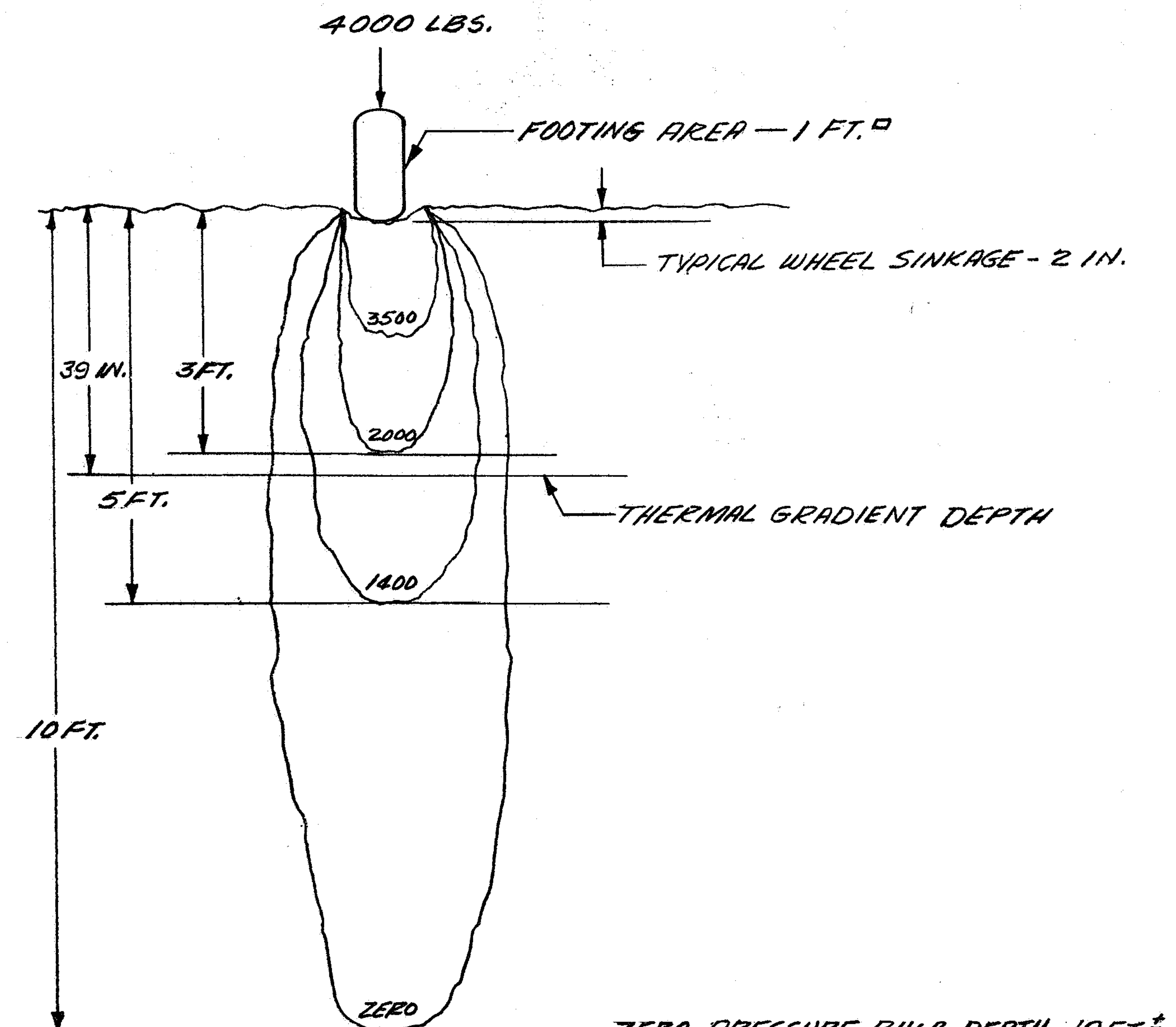


FIGURE C-1 LUNAR SOIL DEPTH CONSIDERATIONS

Reproduced from "Space Manual, Part I, The Moon," Astronuclear Laboratory, Westinghouse Electric Corporation, May 1963

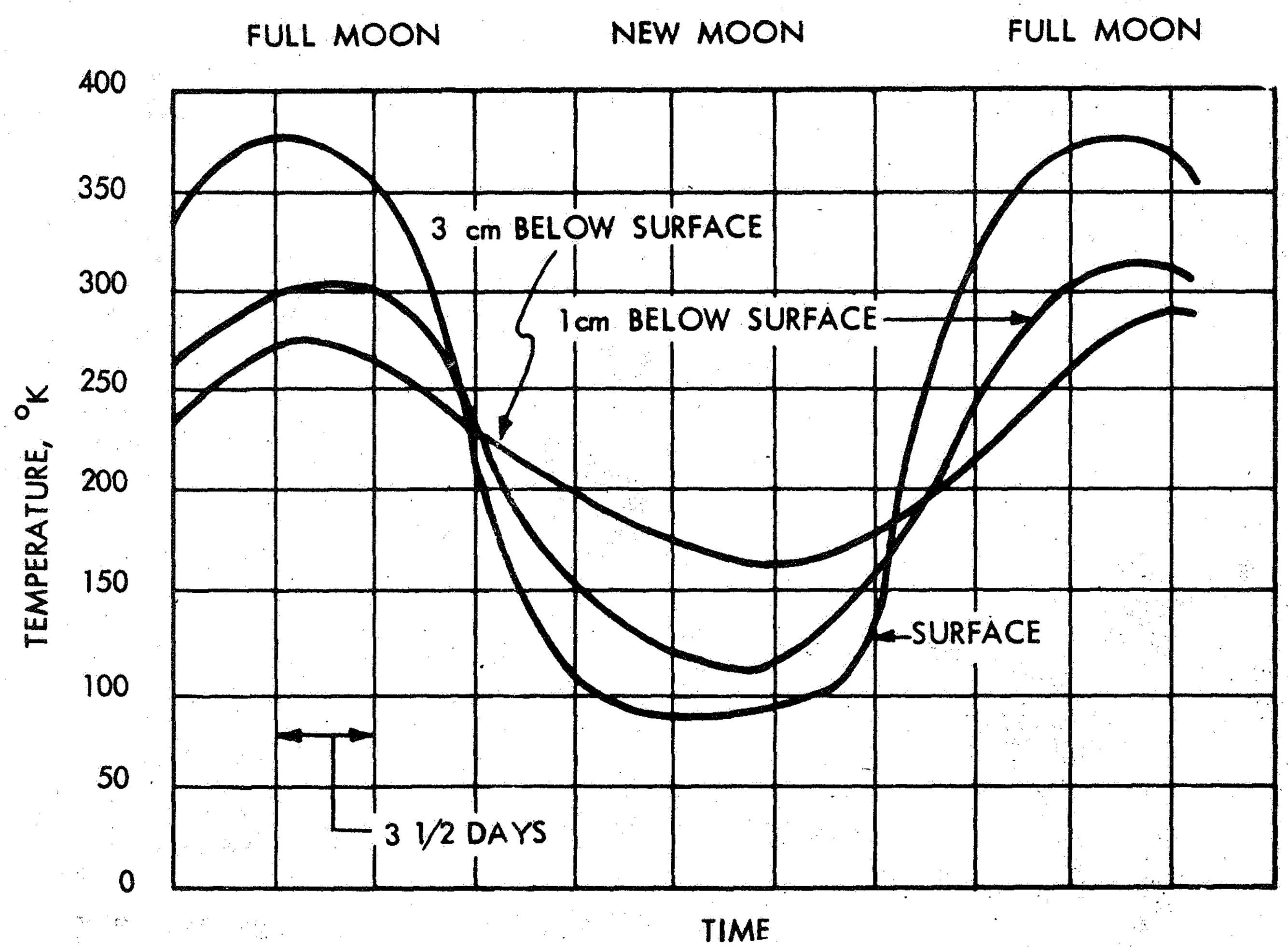


FIGURE C-2 LUNAR TEMPERATURE VS TIME

Following, in the order of priority, are the desired characteristics for a simulated lunar soil for use in engineering tests of subsystems.

a. Maximum allowable outgassing rate, assumed 1×10^{-8} torr liters/sec/cm^2. (during chamber operation at about 10^{-5} torr).

b. Soil density, 1.75 - 2.0 gms/cm^3 (110 lbs mass/ft^3).

c. Thermal conductivity, 1 -3 x 10^{-6} cal/cm^2/sec/degree C.

d. Light reflectivity (albedo), 6-8%.

e. Particle density, 2.5 - 2.7 gms/cm^3 (150 lbs mass/ft^3)

f. Average bearing strength, 12-30 psi.

g. Particle specific heat, 0.2 cal/gm^{o}C.

h. Electrical conductivity, 3.4 x 10^{-4} mhos/meter.

i. Thermal stability range without decomposition, 105^{o}K-500^{o}K.

In addition to compromises which may be necessary in meeting the characteristic criteria, use of soil simulants in a vacuum environment may present problems in contamination of equipment, particularly in instances of rapid repressurization of the vacuum environment disturbing the soil bed. Thus, trade-offs must be considered between vacuum environment trafficability study, versus studies of soil effects under a normal earth atmosphere.

The relationship of soil simulants to actual vehicle testing is discussed further in section F of this chapter.

Surface Treatment

In the absence of a lunar soil simulant, a surface which has the thermal chacteristics of the lunar surface would meet the principal test requirements, lacking only characteristics required for trafficability studies. Ideally, the surface treatment should duplicate the absorptivity, emissivity, and resultant a/e ratio, thermal conductivity and specific heat of the lunar surface. If this could be accomplished, a minimum amount of heating and cooling of the test plane would be required. The heat from the simulated solar beam would be absorbed by the surface, the characteristics of which would cause the illuminated surface to achieve the equivalent +250°F temperature while conforming to the heating curve of the moon. When the simulated sun is moved to a different area or cut off, the test surface could achieve the -250°F lunar surface temperature by virtue of its thermal conductivity and emissivity ratio. This ideal situation is predicated on the test surface having the proper view factor and viewing a 4°K space temperature. Obviously in a space chamber the ideal view factor is not obtainable and the space temperature is 100°K rather than the desired 4°K. In addition, there may not be a surface treatment that can produce all of the desired qualities listed.

The one quality that would contribute the maximum benefit would be a surface treatment capable of producing the proper absorptivity (a), emissivity (e) and resultant a/e ratio. Unfortunately at the present time there is a lack of information regarding the actual a,e, and resultant a/e of the moon itself. Postulated lunar values range from an a/e value of 1.02 (a=0.96, e=0.94) to 1.13 (a=0.96,e=0.85). The difference in final temperature of an object possessing an a/e ratio in this range is insignificant to the test results.

There are many possible surface treatments or coatings which will produce an acceptable a/e ratio. Crushed carbon electrodes (graphite) on polished aluminum produces a 1.06 ratio, but substances such as this would be mechanically impractical for use on the chamber floor. One simple modification is to paint the floor with flat black epoxy resin paint, which on aluminum produces an approximate a=.95, e=.89 (a/e=1.07) while possessing sufficient mechanical strength for use on a lunar plane.

The thermal conductivity of the lunar surface is extremely low (1-3 x 10^{-6} cal/cm^2/sec/degree C) while the thermal conductivity of most metallic chamber floors is approximately .4 cal/cm^2/sec/degree C. A possible solution would be to provide extensive insulation between the floor and a new low thermal conductivity lunar plane. The thermal conductivity effects of the lunar surface as applied to the test object may be reasonably simulated by use of insulating pads under the test objects.

The simulation of specific heat is considered not feasible without a soil simulant, but it is probably the least essential of the thermal characteristics.

D. VEHICLE EXERCISE SYSTEM (VES)

Test Philosophy Requirements

A treadmill to permit exercising the LRV is required by paragraph 8.3.1.12 of the Test Philosophy.

Vehicle Exercise

The purpose in providing a Vehicle Exercise System (VES) is to accomplish the maximum simulation of the actual operating conditions of an LRV traversing the lunar surface. The most desirable system is one which would employ a means of absorbing the vehicle drive power, and/or applying power to the vehicle to simulate braking on down-hill grades, while simultaneously applying various motions and shock loads to the suspension system in order to simulate the traversing of rough terrain. The VES should contain the necessary components to perform the above functions while operating in a chamber producing simulated lunar environment. This discussion is primarily concerned with the power absorption and shock load systems, and does not include such features as instrumentation, control and thermal systems.

There are many possible methods by which operating conditions can be evaluated. Generally, they may be divided into the four categories discussed below: Actual Vehicle Movement; Treadmill System; Drum Drive System; and the Axle Dynamometer System.

Actual Vehicle Movement

The actual powered movement of the test vehicle in a chamber and across the lunar soil simulant would provide the most accurate simulation possible. The maximum vehicle velocity is expected to be approximately ten miles per hour, or 15 feet per second. Even if a 200 foot circular track were available inside a chamber, the vehicle would complete the circle in less than 42 seconds. In addition, it would be difficult to provide continuous solar illumination to a vehicle actually moving at this speed within the chamber. An extensive vehicle road test within a chamber will require a larger chamber than any existing today. If the test is to be conducted in simulated sunlight, a sun capable of tracking the vehicle around the chamber at speeds up to 10 MPH is required.

Treadmill System

The treadmill System may be defined as a flat, moving plane on which the vehicle rests. The vehicle is prevented from moving with the plane, therefore power is applied to or absorbed from the vehicle wheels. Figure D-1 illustrates several configurations of Treadmills.

One of the main problems of a treadmill is the large amount of power required to propel it. A preliminary estimate of 300 HP is required to propel a treadmill of sufficient size to test a 46 foot long lunar roving vehicle. The equivalent heat of over 200 KW presents a difficult thermal load if radiated within the chamber, while cooling by circulating a fluid requires flexible lines and adequate seals. In evaluating any VES, the heat load imposed on the chamber is one of the major considerations.

An equivalent of the treadmill is the conveyor belt, more specifically the flat belt. These belts have a long and satisfactory history of material moving in industry, but their capabilities within lunar environment conditions are questionable. The multiple number of required supporting rollers and bearings, the construction of a flexible belt and the drive system, require extensive engineering analysis to assure the feasibility of a treadmill system. The lubrication, maintenance, and cooling of joint pins in a link belt system presents a complex design problem. A flexible woven wire belt could be utilized but this still requires the multiple roller supports beneath the belt and the life of the belt under constant flexure at the extreme low temperatures would be questionable.

The chamber area and volume required by a treadmill may be expected to be greater than required by most other VES concepts. The treadmill area will normally be equal to or greater than the largest test object, while the diameter of the drive and terminal pulleys will result in a height increase of approximately six feet.

a. Full Length Treadmill.

This treadmill is probably one of the least difficult treadmill systems to construct but provides the least in actual simulation. In this particular case, the treadmill would be approximately 21 feet wide by 50 feet long for testing of the 17' x 46' LRV of the ALSS. The full length treadmill basically can provide only forward and backward speeds for the vehicle. It cannot produce any lateral turning effort of the vehicle, any wheel differential loading, nor can an implanted bump be made to act on a single wheel.

b. Longitudinal Split Treadmill.

This treadmill design has an advantage over the previous one, because by varying speeds of each particular side of the treadmill, differentials between drive systems can be simulated on each side of the vehicle. Thus, the right side could be driving forward with the left side in reverse for a close turn simulation or stationary for a large radius turn. In addition, by placing some obstacle on one side of the treadmill, it is now possible to impose a shock-load, depending on the size of the obstacle, to all wheels on one side of the vehicle. This design, however, cannot shock a given wheel independently nor simulate the turning effort of a particular LRV module.

c. Traverse Split Treadmill.

This treadmill is actually a full-length treadmill cut into appropriate lengths to test each module of the LRV. This treadmill would provide the capability of varying the forward and reverse speeds of any desired module to simulate the pushing or pulling of one module by the others, when climbing over obstacles. In addition, this system would have the capability of shock-loading any single wheel of any module by placing an obstacle on one half of any section of the split treadmill.

d. Traverse and Longitudinal Split Treadmill.

This is a combination of the features of a Longitudinal Split Treadmill and the Traverse Split Treadmill, and becomes equivalent to the Drum-Drive System with the exception that it presents a flat footprint to the LRV wheel rather than a curved footprint.

Drum-Drive System

Figure D-2 illustrates the basic concept of a Drum-Drive Exercise System. It is composed of drums with a power absorption system impeding rotation of the drum. The simplest configuration would be a single drum for each pair of wheels, as shown on the top drawing of the basic concept. In this case, only two or three bearings per drum are required and internal cooling systems could be supplied without undue difficulties. The single-drum system essentially has the characteristics of a full-width traverse split treadmill and therefore cannot provide differential speeds on the wheels of a single LRV module.

a. Split Drum System.

The split-drum system has the advantage of differential speeds per vehicle wheel for each module and is illustrated in the second line of Figure D-2. In this case, the problems of construction and the number of bearings, seals and cooling lines required per module of the exercise system are essentially doubled.

b. Multi-Drum System.

One of the basic disadvantages of a drum system is the fact that the drum presents an incorrect wheel footprint. Figure D-3 illustrates this problem. As shown in this Figure, the wheel footprint provided by the treadmill is equivalent to that of the lunar surface; in the drum system, however, the footprint of the flexible vehicle wheel now tends to curve around the drum. This will impose a continuous stress on the vehicle wheel, which will occur only momentarily in an actual lunar mission. The wheel footprint becomes increasingly valid as the diameter of the drum increases. The vehicle wheel may be from six to ten feet in diameter. A possible multi-drum system to provide a better footprint is indicated as C in Figure D-3. In this case the single drum has been replaced by a multiple number of drums to provide a flatter surface. This system is considerably more complicated than a single drum system, requires a large number of bearings and seals and a complicated power-drive or absorbing system.

c. Summary.

The basic concept of the drum-drive system appears simpler to construct and more dependable than any of the treadmill systems and provides equal or better simulation as compared to the treadmill with the exception of the wheel footprint. The multi-drum system is considered too complicated and is unwarranted to simply achieve a better footprint. The split drum system represents one of the simpler systems capable of actually exercising the LRV wheels.

Axle Dynamometer System

This system is illustrated in Figure D-4. In this particular case, the vehicle is raised above the chamber working surface and the axle dynamometers are attached either to the vehicle wheels or directly to the vehicle axle. Utilizing this system, each wheel can be independently loaded to simulate turning, stalled conditions, free spinning conditions of a given wheel, and various load combinations to single wheels, multi-wheels or simultaneously to the entire vehicle. In addition, the system would require only minor modifications to an existing chamber floor and should result in one of the least expensive systems. Another advantage of the Axle Dynamometer system is its flexibility for testing of various types and lengths of vehicles. If the dynamometers are sized for sufficient horsepower, they may be utilized on two, four or six wheeled vehicles with equal ease, and by simply changing their positions they can accommodate any length of spacing between vehicle wheels. None of the other systems has this flexibility. Still an additional feature is the reliability of the Axle Dynamometer. It represents one of the few closed systems which could be designed, and by its modular nature, a defective dynamometer could be replaced. The failure of any section of a treadmill, or of the drum-drive systems will result in considerable chamber downtime and a probable repressurization of the chamber. Various movements (vertical and horizontal translation) can be incorporated into the dynamometer system to simulate shock-loading of any particular wheel or multiples thereof. The major disadvantage of this system is the lack of actual vehicle wheel exercise, as the wheels would not touch the ground or be under any torque conditions, even if they were on the vehicle. Other disadvantages are the loss of the thermal conductivity between the wheel and the surface. If this system is utilized, a wheel is tested in a chamber with simulated lunar soil to establish numerical values for the above parameters. Once this has been accomplished, equivalent thermal conductivities and power demands could be synthesized in the axle-dynamometer system. A separate test would still be required to establish the validity of the wheel design but this test could be performed in a smaller size chamber.

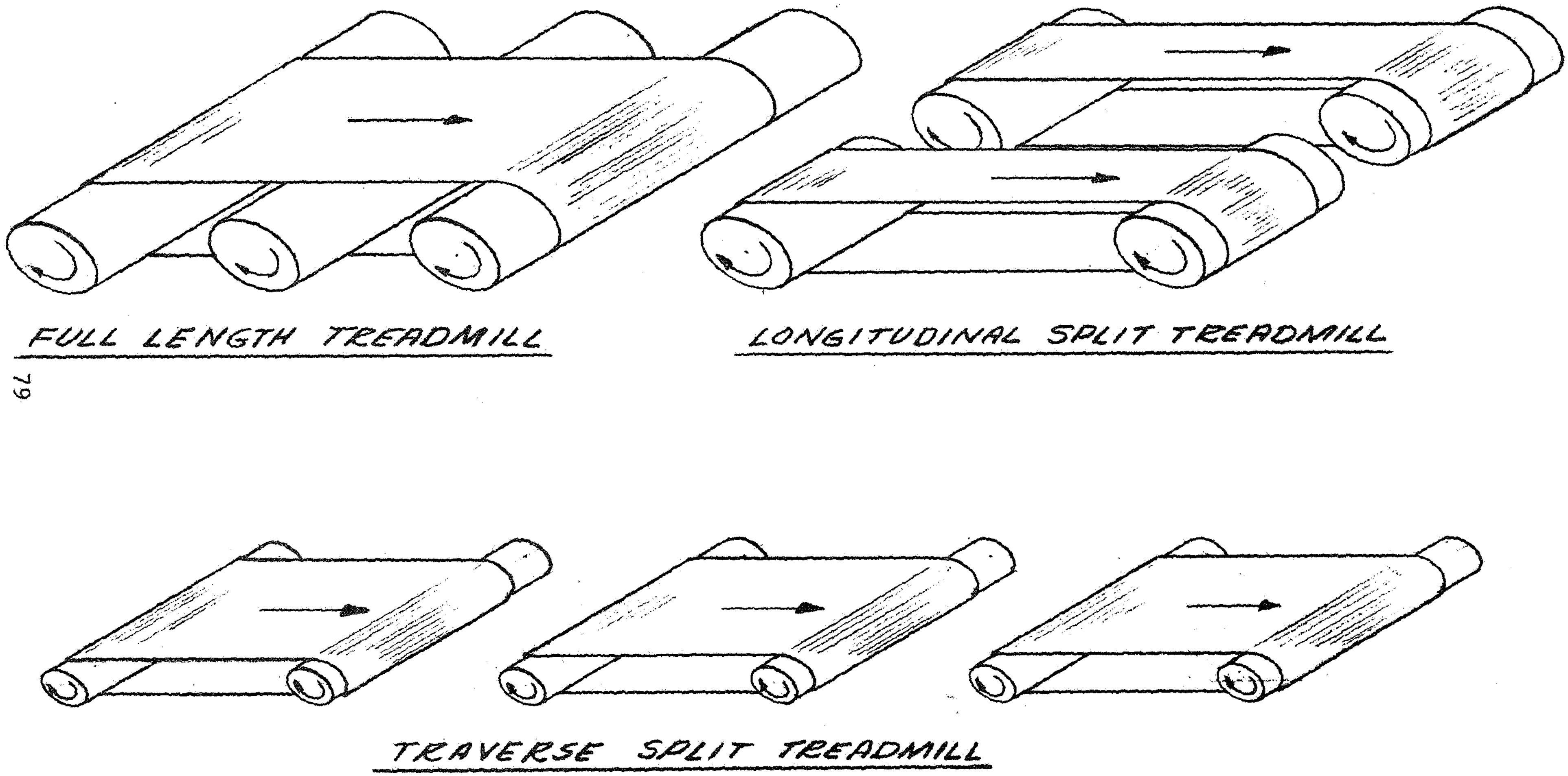


FIGURE D-1 TREADMILL EXERCISE CONFIGURATIONS

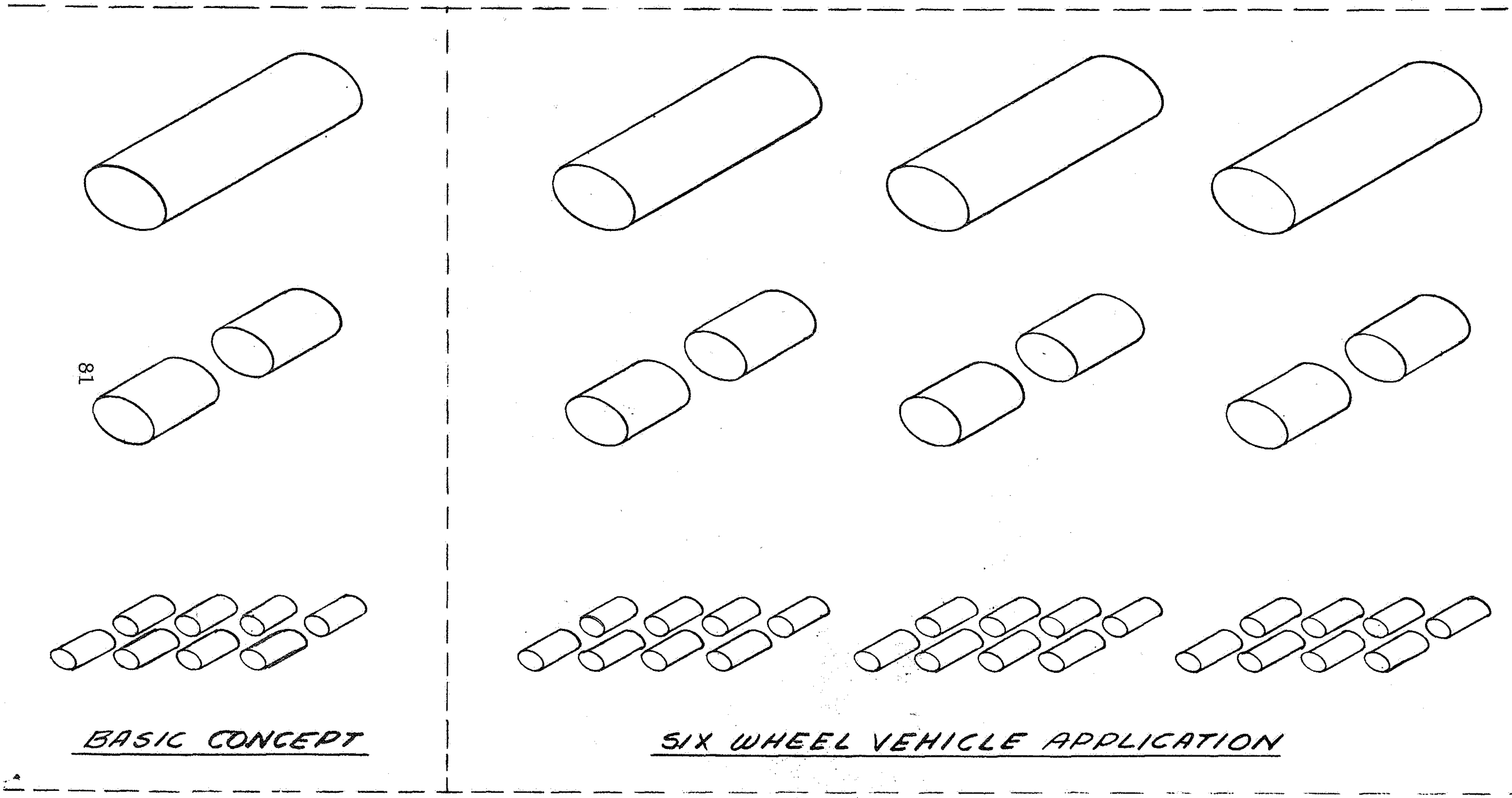


FIGURE D-2 DRUM EXERCISE CONFIGURATIONS

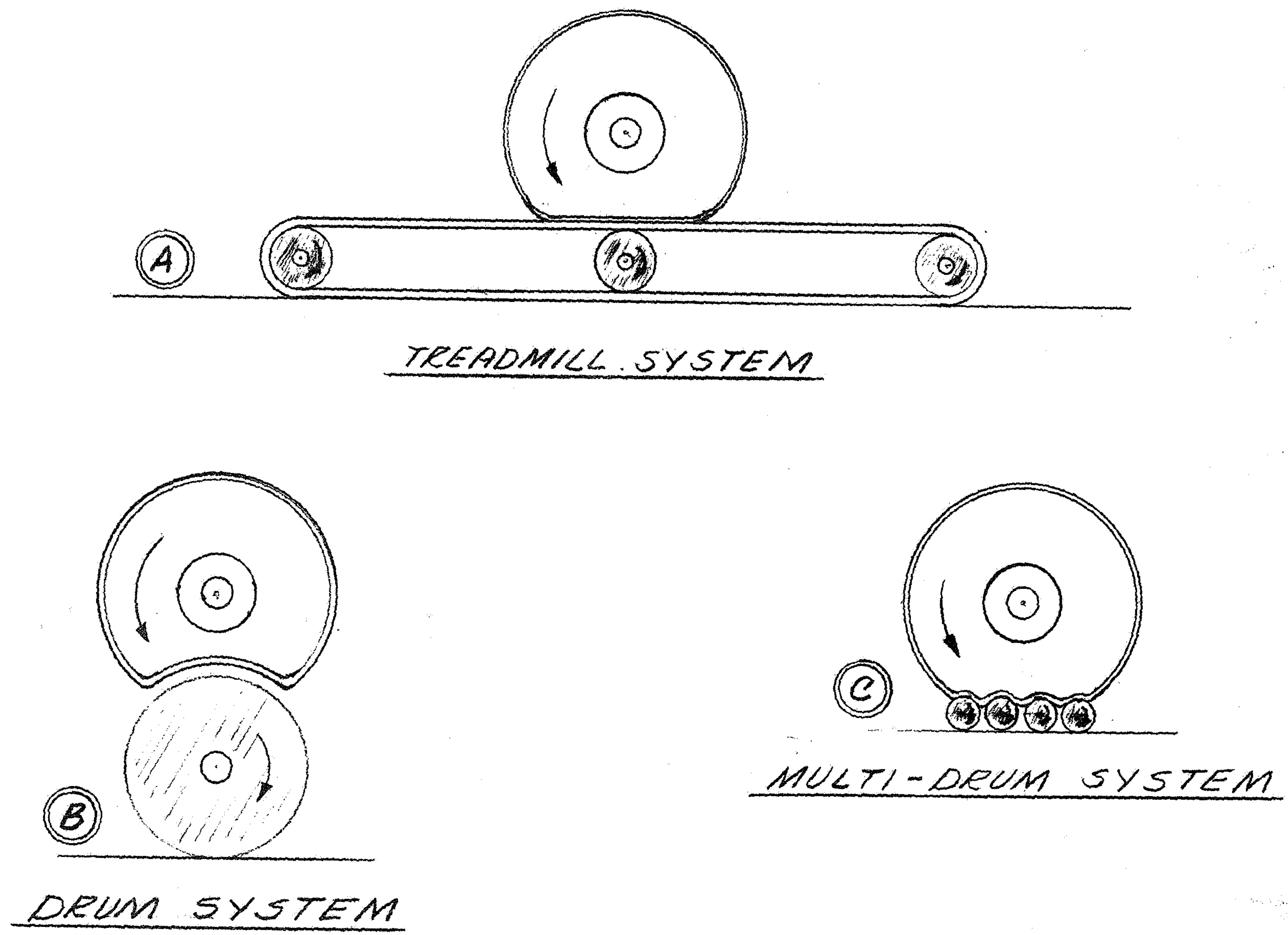


FIGURE D-3 WHEEL FOOTPRINT VS EXERCISE SYSTEM

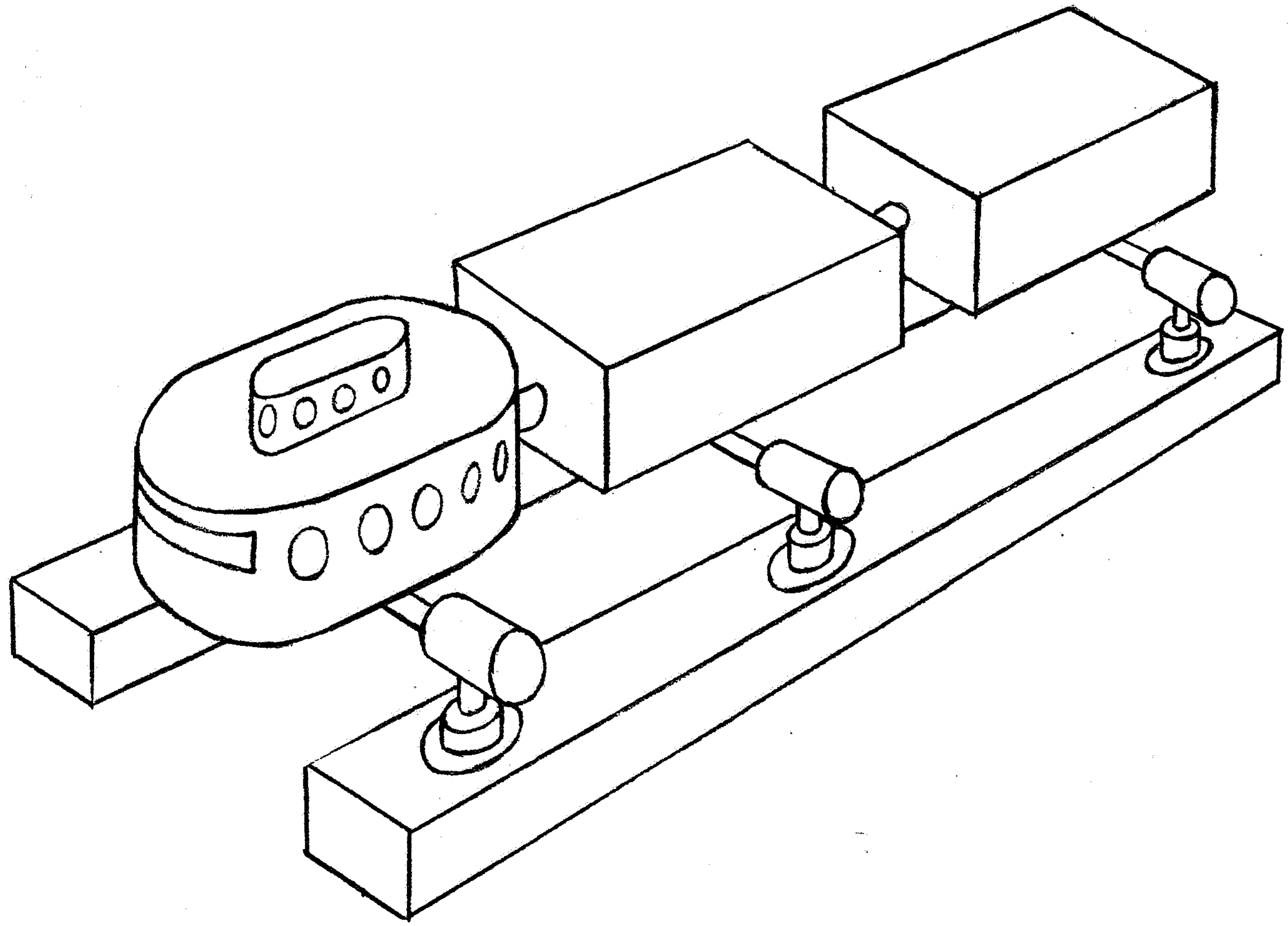


FIGURE D-4 AXLE DYNAMOMETER TESTING SYSTEM

E. TEST OBJECT ORIENTATION

Test Philosophy Requirements

The Test Philosophy does not directly require the orientation of test objects with respect to the solar simulation beam. Paragraph 8.3.1.2 states that a means of varying the movement of the sun is highly desirable. Orientation of the test object with respect to the solar simulation may be accomplished by movement of the simulated sun and/or movement of the test object.

The test object orientation may be considered as a vertical and horizontal azimuth with respect to a given surface of the test object. The vertical azimuth may be provided by an elevating or rising sun or by multiple fixed suns utilized in conjunction with tilting of the test object. The horizontal azimuth may be obtained either by moving the simulated solar source through the required horizontal angle or by rotating the test object. By selection of the vertical and horizontal azimuths the correct simulated solar orientation of the test object surfaces can be obtained. If the horizontal movement of the solar source proves to be infeasible, the rotation of the test object will be required. This rotation may be accomplished by the following means:

a. The object may be manually rotated.

b. Accessory equipment, such as a pivot, may be attached to the test object to provide inherent rotational capability.

c. The chamber may be equipped with the necessary means such as a turn table or special hoisting equipment to rotate the test object.

Manual rotation of large objects, such as the LRV, may be essentially eliminated from consideration because of the weights and sizes involved.

The second method for providing the test object rotation is by the attachment of rotational accessory equipment to the test object. Various degrees of sophistication can be incorporated into such equipment so that tilting and other motion can also be imparted to the test object. The accessory may take the form of circular tracks with an associated frame and wheels placed on the test object, cabling systems which lift and rotate the object, pivoted powered wheels beneath the object, or in the case of an LRV, rotation by utilizing the vehicle inherent capabilities with any necessary modifications. These systems would require minimum modification to existing chamber floors. Such systems are limited in their overall capability because they must be designed to test a specific piece of equipment and in some cases a compromise of the test objectives may occur.

The third method proposes that the means for rotation will be incorporated into the facility by use of turntables or other equipment.

Turntable Capabilities

The number, size and configurations of turntables to be incorporated into a chamber for tests of an LRV or LEM Truck depend to a great extent on the type and magnitude of the desired tests. The major categories of tests and test combinations considered are:

LEM Truck Test

Partial LRV Test

LRV Test

LRV plus LEM Truck Test

Deployment Test

LLV Systems Test

Auxiliary Equipment Tests

In any of the tests the prime turntable requirement is that it be of sufficient size, be capable of supporting the load and turn at the prescribed rate.

System A represents the simplest and smallest turntable for minimum testing. It is composed of a single turntable of 36 feet in diameter. This size provides primarily for testing of a LEM Truck which is 33 feet in diameter across the deployed legs as illustrated in Figures B-1 and B-5, Appendix B.

System B provides a turntable diameter which has been increased from the previous 36 feet to 50 feet. The selection of a 50 foot diameter is based on the requirements for test of a complete LRV with a length of 46 feet. The only major gain of this system over system A is its ability to accommodate the complete LRV; no test capability has been added which would allow deployment tests or combination tests.

System C is composed of a 72 foot diameter turntable which was considered because of its long range potential, such as for LESA system testing. The LESA lunar base concept utilizes the LLV (Lunar Landing Vehicle) instead of the LEM Truck. For the present concept the LLV is 69 feet in overall diameter and weighs up to 28,000 pounds. System C has the capability of singularly testing any piece of the ALSS equipment including the LEM Truck or LRV and can also test the major systems of LESA such as the LLV and shelter.

System D is composed of a 97 foot diameter turntable which allows conducting combinations of tests as well as deployment procedures tests.

In the preceding systems, the orientation of the test objects with respect to each other remained constant. If it is desired to provide orientation of each object individually with respect to the light source then two or more turntables are required.

System E provides two independent turntables of 36 and 50 foot diameters. This would allow the independent orientation of the LEM Truck on the 36 foot turntable and the ALSS-LRV on the 50 foot turntable. Actually there is little advantage for this concept since solar simulation cannot be provided to both objects at the same time, thus only one simulated lunar daylight test can be conducted at a time. Orientation of the LRV with respect to the LEM Truck would provide marginal benefits for tests involving personnel, or provisioning transfer.

System F has two turntables one of 50 foot and the other of 97 foot diameter. In this case, the smaller turntable is located within and turns with the larger turntable. By utilization of this type arrangement it is now possible to conduct a deployment test with selected orientation with respect to the solar source. If the LEM Truck could be landed with a desired orientation then only that particular deployment test need be conducted. Present indications are that prelanded orientation of the LEM Truck is not probable and post-landing reorientation is not desirable. Therefore deployment tests should be conducted with various orientations. A single 97 foot turntable can perform this test, however, it does not provide for a continuation into the LRV test. The two turntable system provides the deployment test with correct orientation and then by use of the 50 foot turntable the LRV test can be conducted.

System G composed of three turntable complex provides even greater capabilities. The largest turntable of 97 foot diameter provides orientation for the deployment tests. A 36 foot turntable orients the LEM Truck independently of the deployment orientation and a 50 foot turntable provides the LRV test orientation.

It can be seen that an increase in the capabilities of turntable systems are accompanied by an inevitable increase in the diameters and complexity. To determine a recommended size and configuration it is necessary to compare the value of each test with the associated cost. Orientation by horizontal rotation of the solar source effectively eliminates the requirement for a test object rotational system. This concept is discussed in detail in Section A.

Tilting Turntable

The feasibility of adding a tilting capability to the turntable has been studied. A tilting turntable would provide for changes in relative elevations of solar simulation, thereby avoiding to some degree the need for a moving solar source. In assessing the merits of a tilting turntable, it was determined that the complexity and engineering problems associated with this feature outweighed the advantages.

F. VACUUM, MANRATING, TEMPERATURE CONTROL AND RADIATION HEAT SINK

Test Philosophy Requirements

Requirements of the Test Philosophy are set forth in Appendix B. Requirements relating to this section are outlined below.

a. Vacuum pumping. This includes mechanical roughing pumps, diffusion pumps, and cryopumps. Specific requirements of the Test Philosophy are as follows:

Vacuum with chamber empty - 10^{-8} torr.

Vacuum with tests in progress - 10^{-5} torr.

MOLAB (LRV) oxygen leakage and outgassing - 12 lb/day.

Test Period - 2 weeks.

Two-man air lock operations per test period - 100.

Outgassing load from soil simulants (not specified in the Test Philogophy - assumed 1×10^{-8} torr liters/sec/cm^2)

Manrating for four men. Normally two will be in the chamber and two in the air lock.

Rated to accommodate a treadmill.

Rated to accommodate a MOLAB (LRV) test vehicle.

Rated to accommodate solar simulation.

Probable hydrogen leakage from vehicle engine-fuel system (not specified in the Test Philosophy).

b. Temperature control and radiation heat sink. Specific requirements of the Test Philosophy for temperature control and radiation heat sink are as follows:

A lunar plane surface temperature ranging from 250°F to -250°F. The rate of change should be equivalent to that occurring on the lunar surface (See Figure F-1).

Simulation of lunar surface thermal characteristics.

A radiation heat sink consisting of absorbing walls cooled to 100°K or less, and capable of absorbing a 10 KW heat load from a test article.

Other requirements are dictated by calculations or analysis in other parts of the report. The requirement for a 10 KW heat sink capacity for the test article is overshadowed by other demands. These are as follows:

Solar Beam	55 KW
Solar Simulator (based on mean degradation of lamps)	475 KW*
IR Beam	82 KW
IR Panel	246 KW
Test Article Power	10 KW
Vehicle Exercise System Dynamometer	5 KW
Radiation from Lunar Plane	545 KW (5,000 sq ft)
Chamber Walls	40-100 KW approx.

c. Manrating. The Space Environment Simulation Chambers under construction at the Manned Spacecraft Center, Houston comprise two large, manrated chambers for the training of astronauts and for testing of spacecraft. The manrating characteristics of these chambers have been established as the criteria for manrating as specified in paragraph 8.3.1.11 of the Test Philosophy.

Calculations

a. Vacuum pumping. The problem of pumping oxygen, hydrogen, and miscellaneous leakage and outgassing appears formidable when one examines the following:

* Based on full cooling of solar simulation modules.

(1) Oxygen Leakage (MOLAB) LRV)

$$\text{Flow (cu ft/sec)} = \frac{WRT}{P}$$

$W = 1.39 \times 10^{-4}$ lbs/sec (12 lbs/day)

$R = 48.31$ (O_2 gas constant)

$T = 180$ degrees Rankine ($100^{o}K$)

$P = 2.78 \times 10^{-5}$ lbs/sq ft

$$\text{Flow} = \frac{(1.39 \times 10^{-4})\ (48.31)\ (180)}{2.78 \times 10^{-5}}$$

$$= 4.35 \times 10^{4} \text{ cu ft/sec}$$

$$= 1.23 \times 10^{6} \text{ liters/sec}$$

(2) Oxygen Leakage (10 KW H-O Fuel Cell)

$W = 9.3 \times 10^{-5}$ lb/sec (based on 5% of consumption rate)

$R = 48.$ (O_2 gas constant)

$T = 180$ degrees Rankine ($100^{o}K$)

$P = 2.78 \times 10^{-5}$ lbs/sq ft (10^{-5} torr)

$$\text{Flow} = \frac{(9.3 \times 10^{-5})(48.31)(180)}{2.78 \times 10^{-5}}$$

$$= 2.9 \times 10^{4} \text{ cu ft/sec}$$

$$= 0.83 \times 10^{6} \text{ liters/sec}$$

(3) Hydrogen Leakage (10 KW H-O Fuel Cell)

$W = 1.04 \times 10^{-5}$ lb/sec (based on 5% consumption rate)

$R = 766.8$ (H_2 gas constant)

$T = 180$ degrees Rankine (100^{o} K)

$P = 2.78 \times 10^{-5}$ lbs/sq ft (10^{-5} torr)

$$\text{Flow} = \frac{(1.04 \times 10^{-5})(766.8)(180)}{2.78 \times 10^{-5}}$$

$$= 0.5 \times 10^{5} \text{ cu ft/sec}$$

$$= 1.5 \times 10^{6} \text{ liters/sec}$$

(4) Miscellaneous Outgassing (N_2, O_2, H_2O, CO_2, etc.)

Soil Simulant - 2.3×10^4 liters/sec (100' x 50')

LRV Structure - 1.79×10^3 liters/sec

LEM Structure - 1.29×10^3 liters/sec

Chamber Walls - trace

Solar Simulation - 2.45×10^5 liters/sec

Lubricants, organic materials, etc. associated with equipment - unknown

(5) Total 20° Condensibles - 3.81×10^6 liters/sec

b. Radiation from the lunar plane. The following calculations indicate the heat radiation from a heated lunar plane to the radiation heat sink. This is based upon anticipated lunar surface temperature when the sun is at its zenith.

$$q = 0.173\, A_1 \left[\epsilon_1 \left(T_1/100\right)^4 - \alpha_2 \left(T_2/100\right)^4 \right]$$

q = BTU/hr

A_1 = Sq ft

T_1 = deg R

T_2 = deg R

$$q = .173 \times 5000 \left[.85 \left(\frac{710}{100}\right)^4 - .96 \left(\frac{180}{100}\right)^4 \right]$$

$$= 1.86 \times 10^{6} \text{ BTU/hr.}$$

$$= 545 \text{ KW}$$

Discussion

a. Vacuum pumping. Of the chambers being considered, many are rated at a vacuum of 10^{-8} torr with the chamber empty. Most of the chambers are operable at vacuums of 10^{-5} torr or better.

Chamber vacuum is achieved by a combination of mechanical roughing pumps, oil diffusion pumps, and cryopumps (LN and LHe panels). Disregarding the mechanical roughing pumps which are generally capable of achieving approximately 100 microns (10^{-1} torr) of pressure, Table F-1 indicates general operating characteristics associated with diffusion pumping and cryopumping. It further indicates that since the test requirements demand a vacuum of 10^{-5} torr, a significant capacity exists within the diffusion pumps and cryopumps for simultaneous removal of condensibles and non-condensibles. However, the problem of oxygen and hydrogen leakage and outgassing is a serious consideration as indicated in the above calculations. A relaxation of the vacuum requirements of the Test Philosophy to 10^{-4} torr would not adversely affect mechanical and thermal aspects of test validity. A relaxation of this order of magnitude would increase the mass flow pumping rate by a factor of 10. This would permit use of chambers which would otherwise require extensive modification. Component testing demanded by the Test Philosophy makes provision for materials evaluation at high vacuum so that this feature of testing is not neglected.

The pumping rate of diffusion pumps is not significantly reduced during the course of continuous operation. Performance of cryopumps, however, is reduced during continuous operation. This degradation is generally a function of condensate buildup. The General Electric Company, Valley Forge Space Technology Center has partially analyzed this problem from theoretical considerations. The parameters of this analysis were as follows:

(1) A 5 KW refrigeration at $20^{o}K$ distributed over 2×10^{6} cm^{2} of cryopanel area.

(2) Gas load of 6×10^{6} liters/sec N_2. Under these conditions, the same for the chamber to degrade from 1×10^{-9} to 1×10^{-5} torr exceeded 20 weeks.

The design of a two-man airlock presents no unusual vacuum problems provided it is considered an extension of the main chamber. Opening the large equipment airlocks into the high vacuum chambers while in operation will, of course, result in unacceptable pressure surges unless the lock is pumped to a low pressure level (i.e. not less than 10^{-3} torr). This will require a relatively large and separate pumping system.

TABLE F-1

OPERATION OF TYPICAL VACUUM FACILITY PUMPS

	Diffusion Pumps	Cryopump
Pressure Range (Torr)	10^{-5} to 10^{-6}	10^{-4} to 10^{-8}
Pump Efficiency		
O_2, N_2, H_2O	High	High
H_2	High	Low
CO_2	High	High
Ar, CH_4	High	Low
Pressure Buildup When Pump Stops	Slow	Fast
Contamination From Pump	High	None
Reliability	Medium	Medium
Extra Mechanical Pumping	Continuous	At start
Power Consumption	High	Medium

The outgassing of soil simulants should not be a serious problem provided properly selected materials are kept free of organic contaminants. The principal outgassing constituent will probably be water vapor. This could be removed by bakeout before installation in the chamber; otherwise, vapor contamination of roughing pump oils and unnecessary condensate buildup may occur.

Oxygen leakage from astronauts (2-3) may range from 5 to 7.5 torr liters per second. This may be accompanied by less significant traces of nitrogen and carbon dioxide. In addition, examination must be made of leakage and outgassing associated with various penetrations, vacuum locks, life support systems, emergency repressurization systems, biomedical monitoring, and medical recovery facilities associated with manrating.

The vehicle exercise system and test vehicle structural and mechanical parts may contribute significantly to the overall outgassing and leakage loads. This problem may be alleviated to a large degree by proper selection of joining techniques, cleaning techniques, bakeout techniques, structural materials, design of lubricated bearings, and care in the use of exposed organic materials. Estimates on outgassing from these devices can only be made when concepts are developed and analyzed.

b. Temperature control and radiation heat sink. The most concentrated load on the heat sink wall will be the direct impingement of the solar simulation when the moving sun is at the rising or setting position. This will equal 140 watts per square foot. General Electric calculations have shown that liquid nitrogen panels can stay below 100°K while absorbing this load. The problem of heat dissipation then becomes primarily a factor of panel area, view factor* and refrigeration capacity. Another major heat load is the radiation from the lunar plane at 250°F.

The thermal characteristics with a rate of temperature change equivalent to that of the lunar surface can be approximated by a combination of the following:

Solar simulation

LN radiation heat sink

Electrical strip heating in the lunar plane

* View factor is the chamber heat sink area and lunar plane area expressed as percentages of what would actually be observed on the real lunar surface.

Liquid or gas nitrogen cooling

Proper surface

Thermal insulation blanket and thermal capacity of the surface

Controls

Investigations conducted for the U. S. Air Force by Boeing have indicated lunar surface temperature variations during a lunation on the lunar central meridian follows a pattern as indicated in Figure F-1. This figure illustrates the typical transient temperatures which should be maintained on the lunar plane.

It is doubtful that the solar simulation in combination with the liquid-nitrogen-cooled walls can reproduce precise thermal simulation conditions for a number of reasons:

(1) The solar simulation modules will blank out an appreciable portion of the heat sink view factor. Furthermore, the test chamber lunar planes are not large enough to subtend an approximate view factor.

(2) The test object will shadow a significant portion of the lunar plane from the solar simulation and will blank out an appreciable portion of the heat sink view factor from the lunar plane.

(3) A rising and setting sun feature would make no provision for the lunar latitude.

(4) The thermal and optical characteristics and behavior of soil cannot be exactly reproduced.

(5) Variations in proximity of vehicle components from solar simulation, heating, and cooling elements. This again is a problem of view factor.

The problem of temperature and radiation heat sink and liquid nitrogen cooled internal equipment are closely associated with cryopumping. The importance of this function can be explained by the chain reaction that would take place if the nitrogen system received transient or sustained overloads.* This would follow a pattern somewhat as follows:

* Cryogenics as Applied to Design and Fabrication of Space Simulation Test Cell, N63-11606, AEDC, USAF, January 1963.

(1) Rise in wall temperature would increase vapor pressure of accumulated condensates causing sublimation and increasing the pumping load (e.g. CO_2).

(2) The increased sublimation would decrease cryopumping efficiency of liquid-nitrogen-cooled surfaces.

(3) Increased wall temperature would result in increased temperature of non-condensible gas molecules entering the helium cryopump.

(4) Combined effects of increased gas temperature, decreased nitrogen surface cryopumping, and condensate release would result in thermally overloading the cryopump. This, in turn, would release the condensates on the helium plates, causing complete breakdown of the required vacuum.

c. Manrating. The following are general requirements associated with manrating.

Four man capacity (normally two in the chamber and two in the manlock).

Manlocks

High reliability for safe human occupancy under normal conditions and safe egress under emergency conditions.

Additional floor area outside the chamber of approximately 9 feet by 10 feet for each manlock.

Manlock doors having a clear width of 42 inches and a minimum height of 7 feet.

Manlock pumping systems for ultimate pressure of 5×10^{-3} torr with a gas inleak of 5.0 torr liters/sec from two suited personnel.

A primary repressurization system for raising pressure from 10^{-5} torr to 207 torr (6psia) in 30 seconds and to provide a partial oxygen pressure of 4.5 psia.

A secondary emergency system to repressurize the chamber from 6 psia to 14.7 psia within 60 seconds.

Fast and slow normal repressurization for 10^{-5} torr in 30 minutes and for 10^{-9} torr to 14.7 psia in 3 hours and a fast normalization pressure from 10^{-5} to 320 torr in 8 minutes.

An environmental control system which provides:

(1) Cooling capacity of 2000 BTU per man per hour (based on water cooled suits).

(2) Total umbilical-pressure suit pressure drop less than 2.0 psi.

(3) Gas flow per suit up to 20 cfm at not less than 15 psia equal to 144 lbs per hour. (20 cfm may be too high because of air velocities and noise involved.)

(4) Breathing and ventilation gas of pure oxygen.

(5) Suit operating pressure between 3.5 and 5.0 psia.

(6) Gas inlet temperatures from 40°F to 70°F and variable relative humidities.

(7) CO_2 partial pressure below 8 torr.

Biomedical monitoring to include surveillance of test subject.

Supporting equipment to include medical facilities and emergency power.

Figure F-2 illustrates an artist's concept of a double manlock, Chamber A, NASA, Manned Spacecraft Center, Houston, Texas.

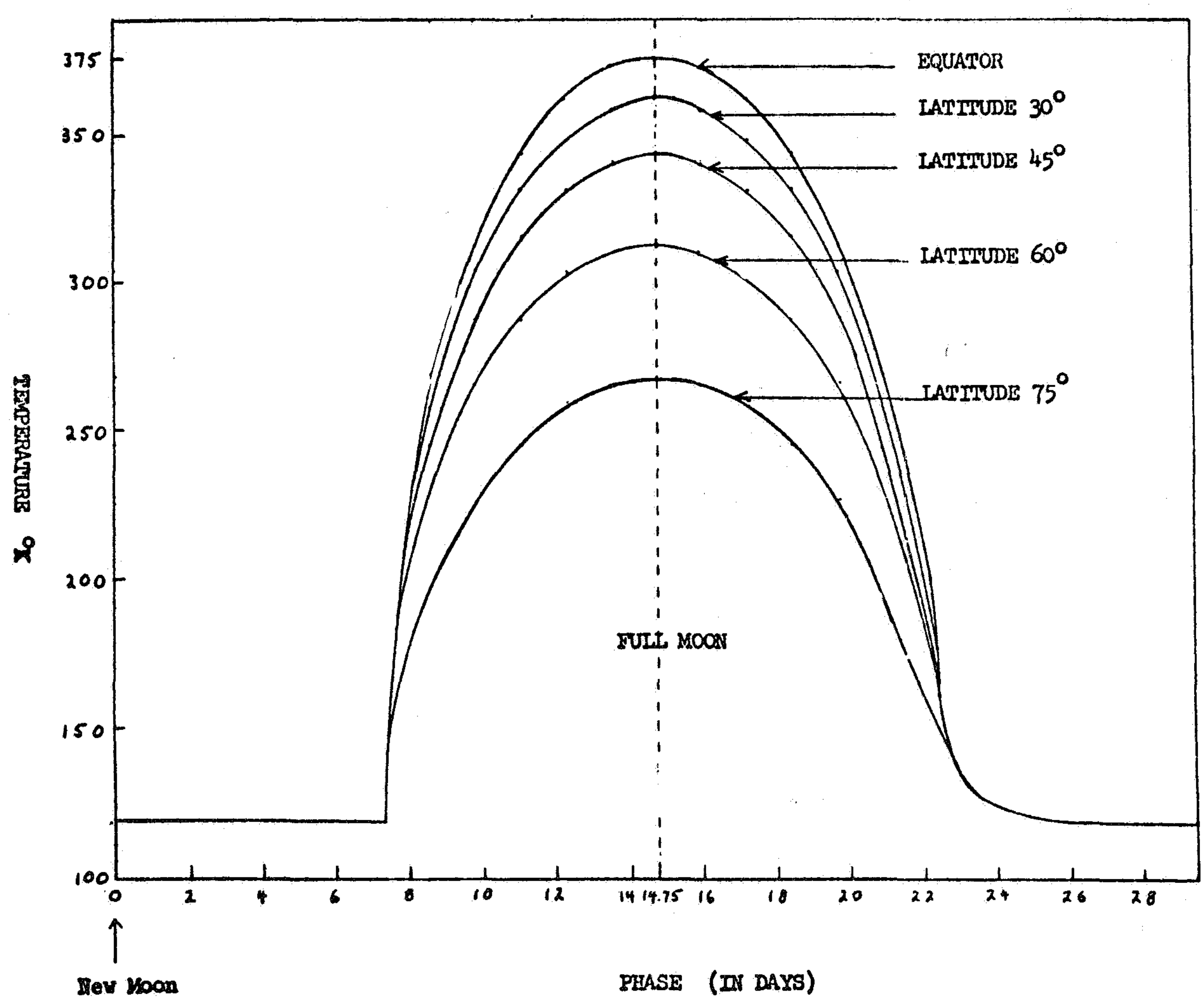
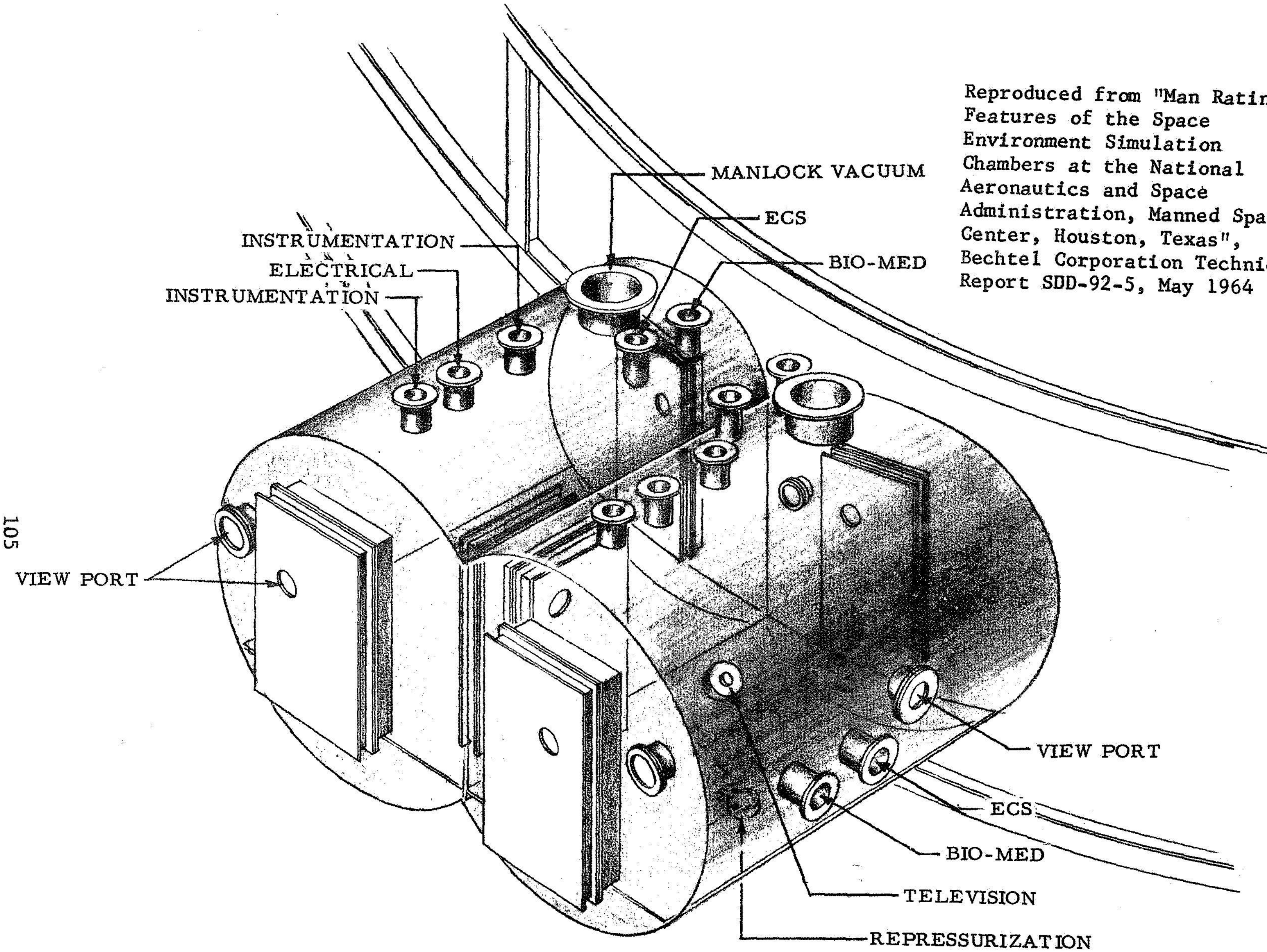


FIGURE F-1

LUNAR SURFACE TEMPERATURE
VARIATION DURING A LUNATION
ON LUNAR CENTRAL MERIDIAN



Reproduced from "Man Rating Features of the Space Environment Simulation Chambers at the National Aeronautics and Space Administration, Manned Space Center, Houston, Texas", Bechtel Corporation Technical Report SDD-92-5, May 1964

FIGURE F-2 DOUBLE MANLOCK, CHAMBER A
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

G. WORKING ENVELOPE AND EQUIPMENT AIRLOCK

Test Philosophy Requirements

The Test Philosophy for Major Systems Testing requires a test chamber of sufficient size to accommodate the largest payload system. For Combined Systems Testing there must be sufficient space within the chamber to unload the LRV and other payloads from the LEM Truck.

Major Systems Testing paragraph 8.3.1.10 requires an airlock of sufficient size to permit insertions of the largest payload system. The ALSS payloads as packaged on the LEM Truck will consist of payloads whose dimensions approximate the frustrum of a right circular cone 10 feet high with an 18 foot diameter base and 15 foot diameter top. For sizing of the airlock to accommodate the LRV only one module of the LRV need be considered. The module dimensions are 16 feet in length, 17 feet in width and 14 feet in height. An airlock or other opening such as a top hatch of sufficient size to permit entry of a loaded LEM Truck is required for Combined Systems Testing.

Working Envelope

The principal spacing needs within the test chamber are as follows:

- Major Systems and Combined Systems test items.
- Solar simulation.
- Infrared panel.
- Vehicle exercise system.
- Working space.
- View factor spacing.

Paragraphs 8 and 9 of the Test Philosophy and Outline Test Program and Equipment Dimension Changes and Amplification Requirements of the Test Philosophy provide dimensional data for Major and Combined Systems Testing. Data for solar simulation, infrared panel, and the vehicle exercise system are included in Sections A, D, and E.

Paragraph 8.3.1.13 of the Test Philosophy specifies a clear distance of 5 feet between articles being tested and the chamber walls. However, it is considered that there are other spacing considerations associated with view factor which are not stated in the Test Philosophy but are of greater importance and warrant special attention. These are as follows:

A minimum distance for view of the lunar plane in all directions from the test object. A distance of 20 feet has been selected as a reasonable approximation of the actual view of the true lunar plane based on the dimensions of the ALSS equipment items. Ten foot high temperature controlled panels at the periphery of the lunar plane would also assist in maintaining the proper view factor.

A minimum spacing from the sun. Based on a vehicle approximately 20 feet in height, a distance of 40 feet has been selected. This would prevent blocking of more than 25 percent of the normal heat sink view from any point on the test vehicle.

Figure G-1 illustrates some problems associated with view factor. The Space Propulsion Facility chamber layout has been used for illustration.

Equipment Airlock

An equipment airlock can provide a means of entry of equipment to the main chamber without the necessity for repressurization of the chamber. It can also serve as a less sophisticated test chamber. In considering solely the equipment airlock without considering other factors, it appears that floor area which may be needed for a Combined Systems deployment test could be provided through use of the equipment airlock. For this usage the airlock door to the main chamber would be open, the loaded LEM Truck positioned at the opposite side of the chamber, and the LRV partially deployed into the equipment airlock.

One disadvantage, however, to the utilization of the equipment airlock for supplementing the chamber space is the inability to properly irradiate the airlock from the solar simulation system. It would, however, be possible to position the solar beam thus irradiating the LEM Truck or an adjacent area and allowing the LRV to pass through the beam on deployment. This may create inaccurate thermal gradients, but on the other hand might be indicative of conditions occurring on shadowed areas of the vehicle on the lunar surface.

Another disadvantage is that the view factor is limited, however on a temporary basis, such as the time interval required for a deployment operation, this may not be serious.

Other test facility requirements and spacing needs within the test chamber dictate the chamber size. Even though an equipment airlock may seem to provide the added space, evaluation of the other requirements may prove the space to be inadequate.

The equipment airlock is to be sized to accommodate the following payloads.

The first is the LEM Truck payload which is a frustrum of a right circular cone with a base diameter of 18 feet, a height of 10 feet and a top diameter of 15 feet. The second is the ALSS shelter laboratory of the same dimensions as the LEM Truck payload and the third is a module of the LRV with a length of 16 feet, a width of 17 feet and a height of 14 feet. A Lunar Flying Vehicle (LFV) is also to be considered, however an equipment airlock capable of accepting the other payloads can accept the LFV.

The length and width of the airlock are determined by the diameter of the LEM Truck payload since it represents the maximum horizontal dimensions, while the LRV establishes the height requirement. The minimum test object envelope is therefore 18 feet in diameter by 14 feet high. A clearance of at least 3 feet is required between the test objects and airlock surfaces for test setup and test object installation and removal.

The ability to conduct tests in the airlock necessitates the incorporation of thermal control panels within the airlock. These require approximately 3 feet of clearance between the airlock inner wall and the panel. The minimum size equipment airlock then becomes 30 feet wide by 30 feet long by 23 feet high. Provision must also be made for the door opening clearance for airlock ingress and egress from the chamber. A single door is proposed since split or sliding doors are more complex for a vacuum application and present both sealing and structural problems. A 20 foot wide by 16 foot high door would permit entry of the test objects.

The final minimum internal size of the airlock would then be approximately 30 feet wide by 44 feet long by 23 feet high. When considering the modification of an existing chamber for addition of an equipment airlock, changes in the proposed airlock size may be necessary for adaption to an existing facility.

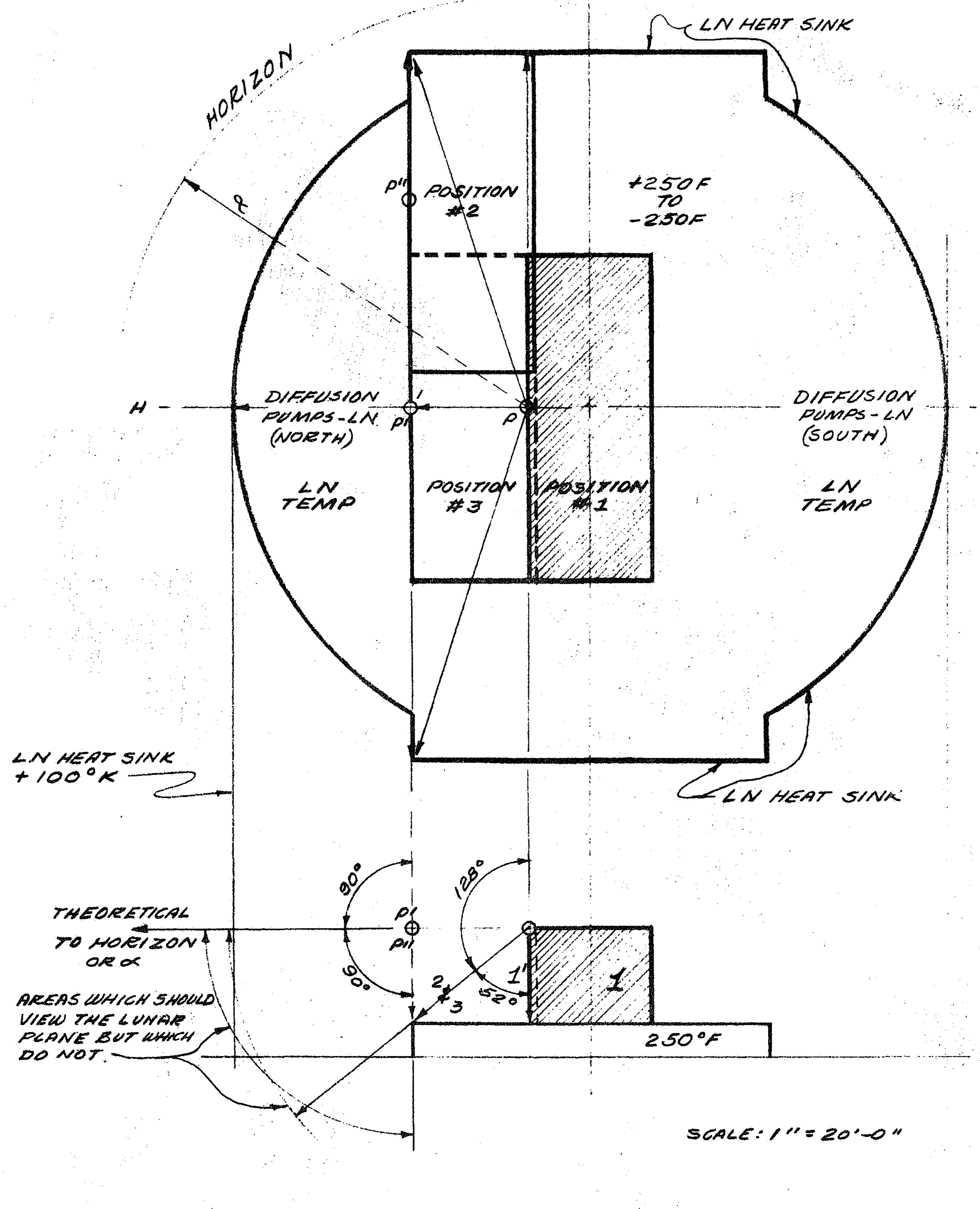


FIGURE G-1-SOME PROBLEMS ASSOCIATED WITH VIEW FACTOR

CHAPTER V

EVALUATION OF CHAMBERS

In this Chapter is presented an evaluation of the chambers contained in Appendices C and D to determine their capability to fulfill the test facility requirements for the Apollo Logistic Support System Payloads. The evaluation has been made on the basis of the test facility requirements for Major Systems Testing and Combined Systems Testing as contained in paragraphs 8.3.1. and 9 of the Test Philosophy and Outline Test Program for Apollo Logistic Support System Payloads.

A. SPACE PROPULSION FACILITY, NASA LEWIS RESEARCH CENTER PLUMBROOK STATION, OHIO

1. MAJOR SYSTEMS TESTING

Working Envelope

The Space Propulsion Facility was designed primarily to test nuclear power systems which do not require large floor areas, but require radiation shielding. The chamber is therefore constructed of a massive concrete outer shell with an aluminum inner shell. In this facility the diffusion pumps are placed in the chamber floor rather than in the walls. The location of the pumps presents one of the major disadvantages of the Space Propulsion Facility for testing ALSS Payloads. The inner chamber diameter of 100 feet provides the minimum size for a deployment test of the LEM Truck and LRV but the addition of a moving sun will reduce the available working area in this chamber.

The chamber is a hemispherical domed double-walled cylinder. The outside cylinder of concrete construction is intended for radiation shielding; it affords no advantage for the ALSS test purposes. The inside cylinder has a nominal diameter of 100 feet, but due to the location of the diffusion pumps in the floor, the actual usable surface area shown on Figure V-1 is 50 feet by 100 feet. The additional working area shown on Figure V-1 is presently utilized as a chamber entrance through a small one-man airlock system.

Figure V-2 shows the effective working area with the 46 foot LRV in place and the solar simulation at morning or evening position. The LRV could be positioned within the solar beam to allow radiation of any selected vehicle module; likewise there is sufficient width of working area to turn the vehicle to secure any desired orientation to the beam. However, if the LRV is turned 90° and still positioned on the 50 foot by 100 foot working surface, the front of the vehicle will only be about 4 feet from the solar simulator. A distance of at least 20 feet should be maintained from the simulated solar source to the test object in order to provide beam uniformity and provide a better view factor. A possible solution to this problem is to displace the vehicle to the opposite side of the chamber as illustrated in Figure V-3. This position is poor because the platform supporting the vehicle or the vehicle itself will block some of the diffusion pumps. Unlike mechanical vacuum pumps, the high vacuum diffusion pump must have a good view angle to the chamber in order to capture and pump air molecules. In addition to the pumping loss caused by the location of the LRV, the solar simulation unit will degrade additional pumps when near the North or South horizon. Utilizing this arrangement and with a working area sufficient to contain the LRV, the maximum number of pumps will be blocked when the sun is on the north horizon and the LRV is oriented at 45° to the incident light.

Figure V-4 illustrates the LEM Truck in test position. All clearances are satisfactory and the LEM Truck may be tested in the chamber without physical difficulty.

An east-west (EW) test orientation is shown in Figure V-5. In this configuration the distance between the front of the LRV and the solar source is adequate (approximately 27 feet) and if the vehicle is rotated for different solar orientations none of the diffusion pumps will be blocked. Figure V-6 shows that a distance of up to 45 feet between solar source and LEM Truck may be obtained in this test orientation.

Figure V-7 illustrates a vertical section of the Space Propulsion Facility with the LEM Truck and LRV in place. The vertical height to the beginning of the dome structure is 122 feet. The highest test object which is the loaded LEM Truck with legs deployed has a height of 22 feet. Allowing a 20 foot separation between test object and solar source plus 20 feet for the physical size of source itself produces a system height requirement of 62 feet. The Space Propulsion Facility therefore has more than sufficient height for all ALSS systems tests.

Chamber Entrance

There are two large doors for entrance into the chamber. Each door has a nominal opening of 50 feet by 50 feet. A door with a LEM Truck in position is shown in Figure V-8. There will be at least eight feet clearance between the LEM Truck legs and the door opening and 28 feet from the top of the LEM Truck to the top of the door opening. Disregarding the possible door modifications required for attachment of the equipment airlock, it can be concluded that the present Space Propulsion Facility door size is sufficient to admit any of the ALSS equipment.

Vacuum

This test facility meets the requirement for a minimum operating pressure of 10^{-8} torr with chamber empty. However, it cannot maintain a vacuum of 10^{-5} torr during testing because of two major factors. The first is the oxygen outgassing of the LRV (MOLAB). The second is the oxygen and hydrogen leakage from the LRV hydrogen/oxygen fuel cell and fuel storage system.

The pumping capacity of this facility is as follows:

Diffusion Pumps............1.5×10^6 liters/sec
100°K Condensibles LN......500×10^6 liters/sec
20°K Condensibles G He.....None

Calculations in Chapter IV indicated the required capacity of the 100°K condensibles in the chamber heat sink walls. There is insufficient diffusion pump capacity to account for the 20°K condensibles which may total 3.81×10^6 liters/sec.

Heat Sink (100°K)

Liquid nitrogen cooling is provided in the chamber walls to produce a surface temperature of approximately 100°K. It is anticipated that this surface will be treated with a coating to provide the required optical characteristics for a radiation heat sink. These characteristics meet the requirements of the Test Philosophy, paragraph 8.3.1.4. The capacity of the heat sink does not meet other demands in heat load dictated by factors discussed below.

Lunar Plane Temperature Control

The requirement of a temperature range of +250°F to -250°F equivalent to that occurring on the lunar surface demands gaseous nitrogen cooling for simulation of the lunar night surface temperature. It will also require electrical strip heating to supplement solar simulation for lunar day surface temperature. To accurately simulate conditions, there must be a programmed thermostatic control on a unit area basis. This control on a unit area basis must be provided to assure approximate lunar surface temperature in spite of shadowing by the test vehicle or other unnatural gradients resulting from heat build-up or heat losses. The facility as now designed makes provision for lunar surface cooling by liquid nitrogen. It does not provide all the features of lunar plane temperature control which are necessary to meet the requirements of the Test Philosophy.

View Factor

This facility does not reproduce thermal conditions approximating the lunar environment. No provision is made to accurately approximate a lunar surface extending to the horizon or to assure a space heat sink for a near full hemisphere. The limited lunar plane, and the diffusion pump area preclude the first condition. Likewise, the introduction of a moving sun panel in the present working envelope would limit an appreciable area of the simulated space heat sink.

Manrating

This facility does not have manrating features; however, manrating can be provided.

Sustained Operation

The chamber is designed for 90 day sustained test operation. Therefore, it can be assumed that the chamber meets the two week sustained operation requirement for those loads and conditions for which it is designed.

10 KW Heat Load

This facility is provided with 3,750,000 BTU/hr refrigeration minus 512,000 BTU/hr diffusion pump baffle heat load. It is estimated that the total load is as follows:

Heat Loss Thru Chamber Walls	94 KW
Solar Beam	55 KW
Solar Simulator (based on mean degradation of lamps)	475 KW
IR Beam	82 KW
IR Panel	246 KW
Test Article Power	10 KW
Vehicle Exercise System	5 KW
Radiation from Lunar Plane	545 KW
Total	1512 KW (5.15×10^6 BTU/hr)

The above figures indicate that there is inadequate refrigeration available to meet the total demand.

Chamber Clearance

The size of the chamber is sufficient to provide a clear distance of five feet between articles being tested and the chamber wall.

Solar Simulation

Solar simulation is not included in the current construction program; however, it is proposed for the NASA Lewis Research Center FY 66 Budget program to be installed for use in 1967. The solar simulation as planned by NASA LRC would not serve as a simulated moving sun, and would not include extension of the solar spectrum beam by a supplementing thermal beam. Because of the requirements for nuclear engine tests, the solar simulating modules must be located in the chamber and fabricated from low neutron cross section materials. For this facility "canned" 5KW Xenon lamp modules have been conceived by Honeywell. These modules are discussed in Chapter IV, and the module proposed by this study for the "moving sun" concept would utilize the 5KW "canned" module. The Honeywell concept provides for alternates of overhead and side sun by alternate assembly positions for lamp modules. The total area of irradiation planned by the Lewis Research Center is 500 square feet, and the module racks will be designed to permit flexibility in establishing the target pattern. The 5KW module, and the nesting of modules has been schematically shown in Figures A-7 and A-8.

The target radiant intensity will be adjustable from 0.5 to 1.2 solar constants which includes the Test Philosophy requirement for ALSS Payloads of 140 watts per square foot.

Hence, it is seen that the facility as designed does not provide features required by the ALSS Test Philosophy. Revision in concept of the solar simulation system would be necessary.

Earth Shine

No capability exists or is planned by Lewis Research Center for earth shine simulation.

Test Object Orientation

The Space Propulsion Facility is not equipped with any means for the orientation of a test object. Orientation would have to be accomplished by manual test object movement or in the case of the LRV orientation may be accomplished by self-propelled movement.

Solar Horizontal Azimuth Orientation

In the present design there is no method, such as a turntable, for providing test object orientation with respect to the simulated solar beam. The moving sun concept, however, eliminates this need.

Lunar Soil Simulant

The incorporation of a lunar soil simulant into a space simulation chamber is discussed in Chapter IV Section C. It was indicated that the two principal benefits to be derived from the use of the soil simulant would be a means for trafficability tests and the simulation of lunar surface thermal conditions.

The Space Propulsion Facility is not presently designed for the use of a lunar soil simulant. The main objection to the use of a lunar soil simulant in the chamber as presently designed is due to the location of the diffusion pumps in a portion of the chamber floor.

The thermal view factor of the pump area of the chamber floor is such that a minor improvement provided by a soil simulant in the working area would be of little benefit. Since the advantages of a lunar soil simulant are marginal for testing ALSS Payloads, the use of a soil simulant in the Space Propulsion Facility is not recommended.

Surface Treatment

The Space Propulsion Facility working area has an aluminum floor which would have an a/e ratio of 3.00 or higher. This characteristic will cause an incorrect temperature condition under solar simulation. One modification would be to paint the floor with flat black epoxy resin paint, which on aluminum produces an approximate $a = .951$, $e = .89$ ($a/e = 1.07$) while possessing sufficient mechanical strength for use on a lunar plane.

The thermal conductivity of the lunar surface is extremely low ($1\text{-}3 \times 10^{-6}$ cal/cm^2/sec/degree C) while that of the Space Propulsion Facility floor of aluminum is approximately .4 cal/cm^2/sec/degree C. A possible solution would be to provide extensive insulation between the floor and a new low thermal conductivity lunar plane and install floor coils for a liquid nitrogen system for floor cooling. The extensive modifications required do not appear warranted for this slight increase in test accuracy. The thermal conductivity effects of the lunar surface may be reasonably simulated by use of insulating pads under the test objects.

Equipment Airlock

There is no equipment airlock as required for Major Systems Testing. A concept for an airlock has been developed and is shown on the drawings for modification of the Space Propulsion Facility.

Vehicle Exercise System

No vehicle exercise system is included in the present design. A system such as a dynamometer can be installed on the working surface for exercise of the LRV.

2. COMBINED SYSTEMS TESTING

Working Envelope

The working area requirements are more severe for Combined Systems Testing than for Major Systems Testing. It is physically possible to position both the LRV and the LEM Truck on the 50 foot by 100 foot working surface in a tandem arrangement. The minimum distance required is 79 feet. Utilizing a ramp for the unloading operation, the minimum distance required for a deployment test is 91 feet. For this condition the 5 foot clearance cannot be maintained between each test object and the chamber wall, neither is there room for a 20 foot diameter translating solar simulator. The space in which to maneuver the LRV will be very limited. The view factor to the chamber walls is inadequate due to the close proximity of the test objects to the walls. The view factor to the lunar plane is limited due to the location of the diffusion pumps in the floor.

Chamber Entrance

Same as for Major Systems Testing

Vacuum

The vacuum requirements for Combined Systems Testing are essentially the same for Major Systems Testing. The major problem will be additional oxygen and hydrogen leakage from two vehicle engine fuel systems instead of one (LEM Truck and LRV). This condition, as well as conditions for Major Systems Testing, will preclude meeting the Test Philosophy requirement of 10^{-5} torr vacuum during testing. Based on a LEM 2.5 KW hydrogen-oxygen fuel cell system, it is estimated that the following additional pumping load will appear:

Oxygen leakage $.21 \times 10^{6}$ liters/sec

Hydrogen leakage 0.4×10^{6} liters/sec

Pumping Capacity

Pumping capacity for $20^{o}K$ Condensibles will be insufficient for Combined Systems Testing for the reasons outlined in the above paragraph. In addition, blocking of diffusion pumps may occur in positioning the test vehicles for certain solar simulation tests.

Total Requirement	4.21×10^6 liters/sec
Diffusion Pumping	1.5×10^6 liters/sec
Additional Capacity Required	2.71×10^6 liters/sec

Heat Sink ($100^{o}K$)

Same as for Major Systems Testing.

Lunar Plane Temperature Control

Same as for Major Systems Testing.

View Factor

The problem of view factor is compounded in Combined Systems Testing. This is particularly true where positioning vehicles for certain solar simulation tests places the vehicle sides directly adjacent to the diffusion pumps or immediately adjacent to the chamber walls (See Figure G-1).

Manrating

Same as for Major Systems Testing.

Sustained Operation

Same as for Major Systems Testing.

10 KW Heat Load

Same as for Major Systems Testing. There will be an increase of 2.5 KW in heat load associated with the LEM power plant.

Chamber Clearance

The size of the chamber is not sufficient to provide the 5 foot clearance between the chamber surfaces and the test object when considered in conjunction with the space required for the solar simulation and the test objects.

Solar Simulation

Same as for Major Systems Testing.

Earth Shine

Same as for Major Systems Testing.

Test Object Orientation

Same as for Major Systems Testing.

Solar Horizontal Azimuth Orientation

Same as for Major Systems Testing.

Lunar Soil Simulant

Same as for Major Systems Testing.

Surface Treatment

Same as for Major Systems Testing.

Equipment Airlock

None is required for Combined Systems Testing.

Vehicle Exercise System

Same as for Major Systems Testing.

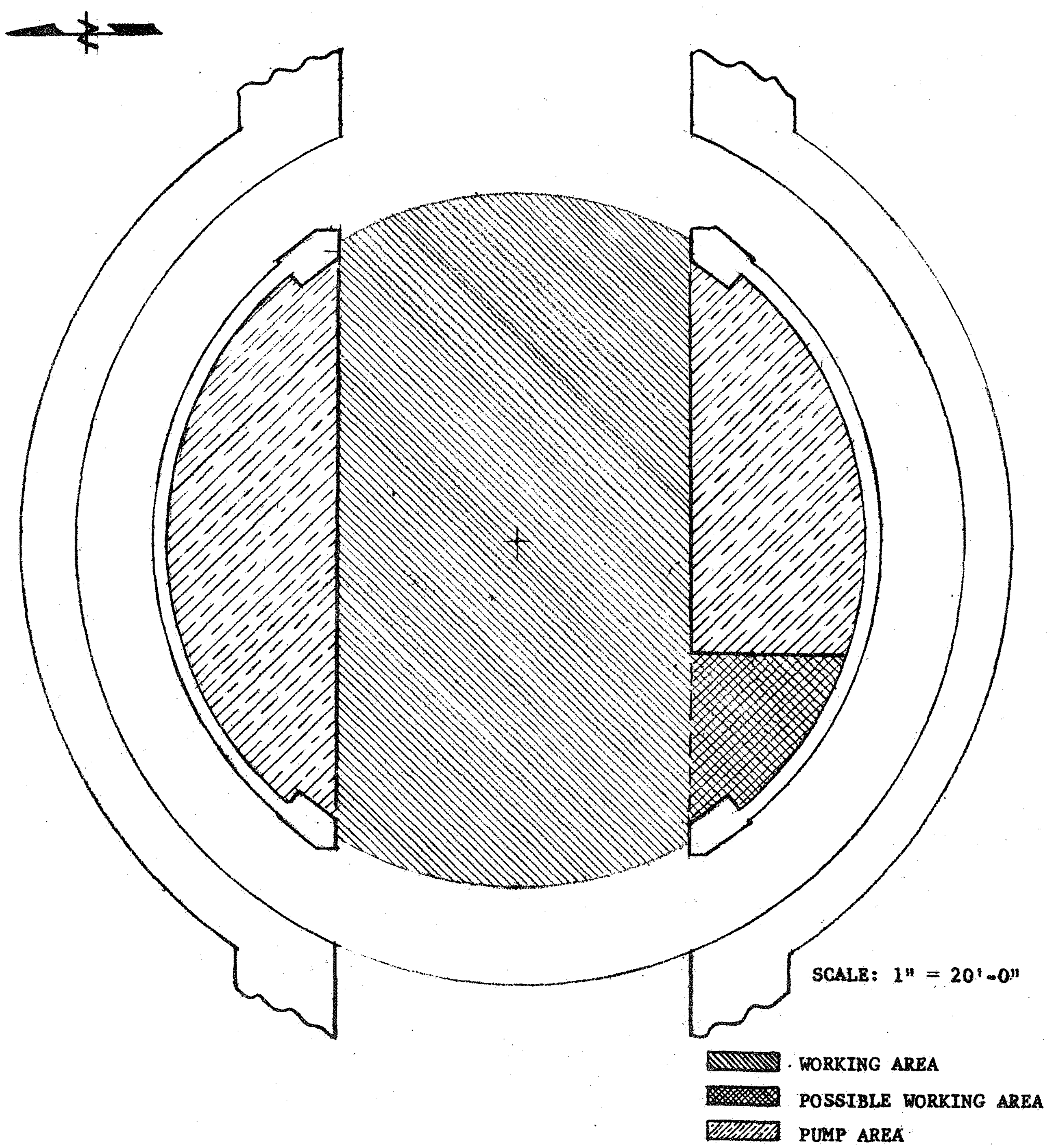


FIGURE V-1 SPACE PROPULSION FACILITY AVAILABLE FLOOR SPACE

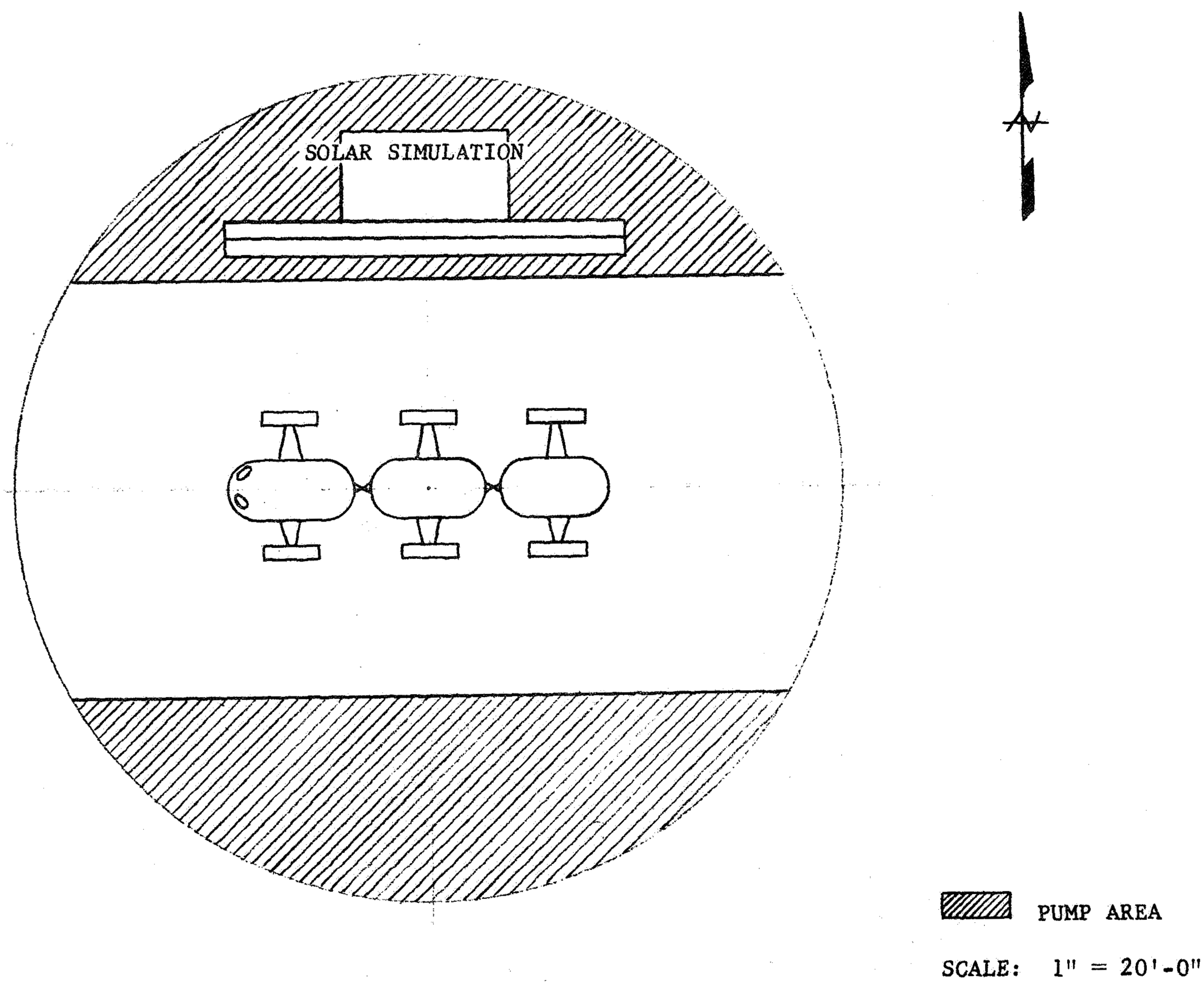


FIGURE V-2 SPACE PROPULSION FACILITY WORKING ENVELOPE

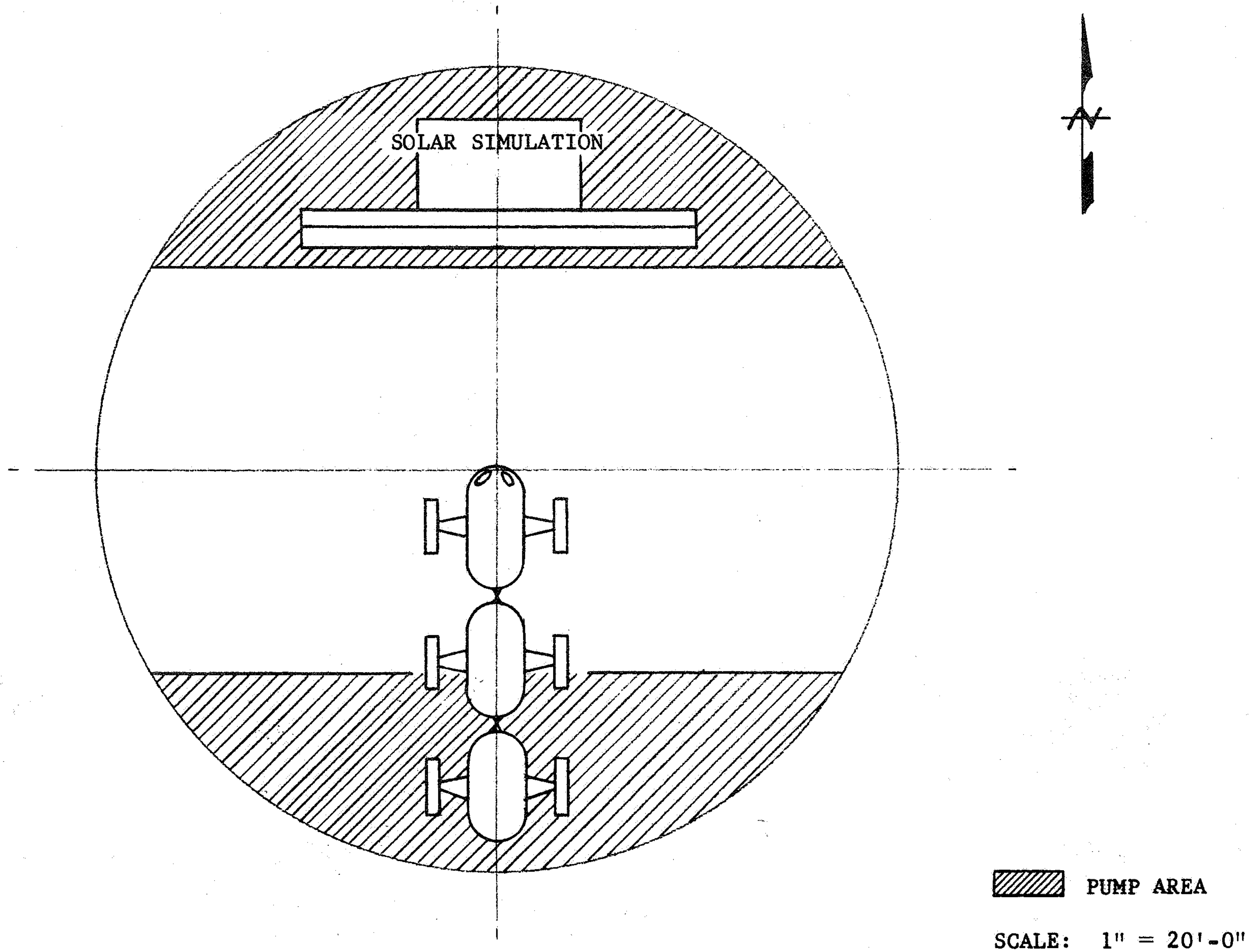


FIGURE V-3 SPACE PROPULSION FACILITY WORKING ENVELOPE

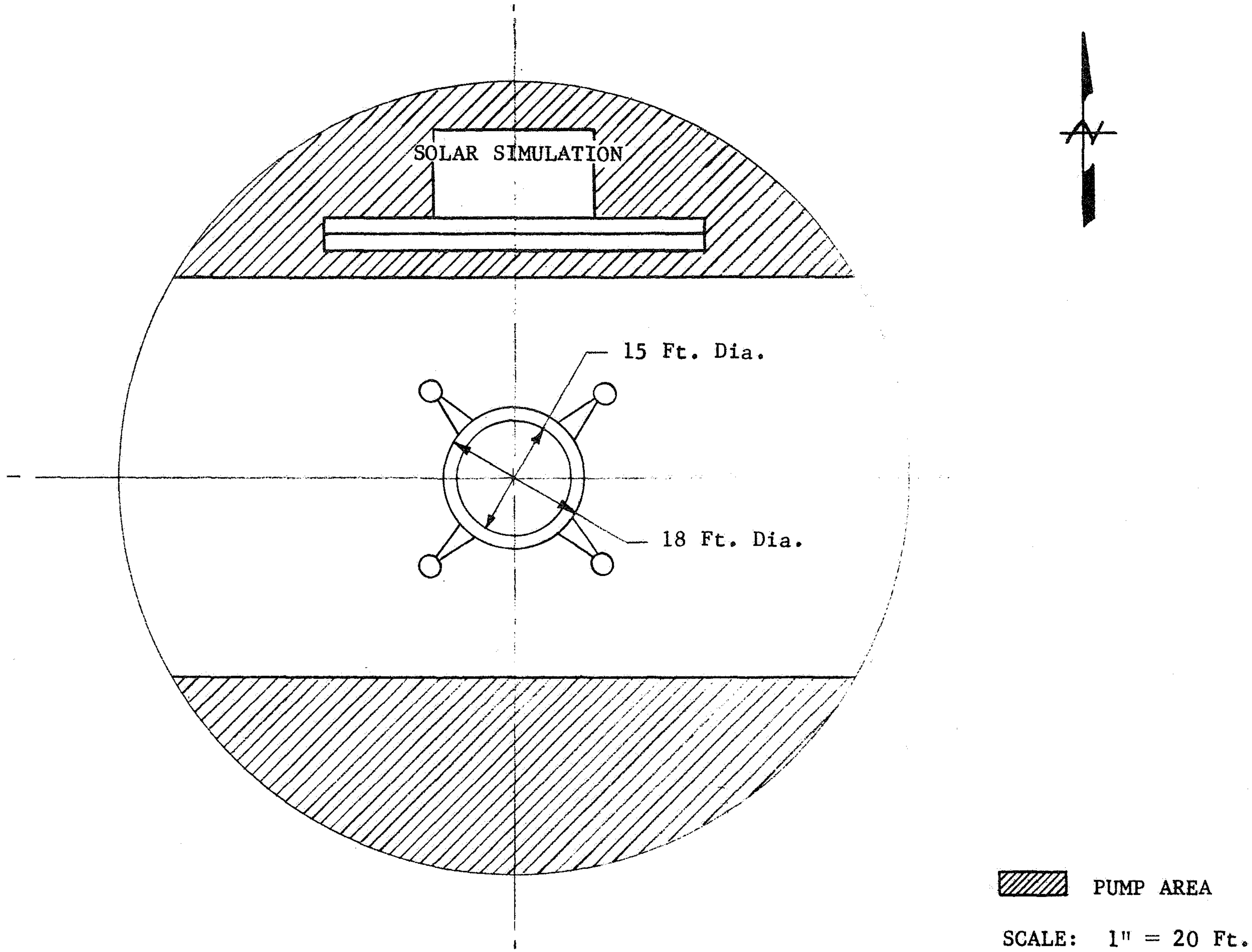


FIGURE V-4 SPACE PROPULSION FACILITY WORKING ENVELOPE

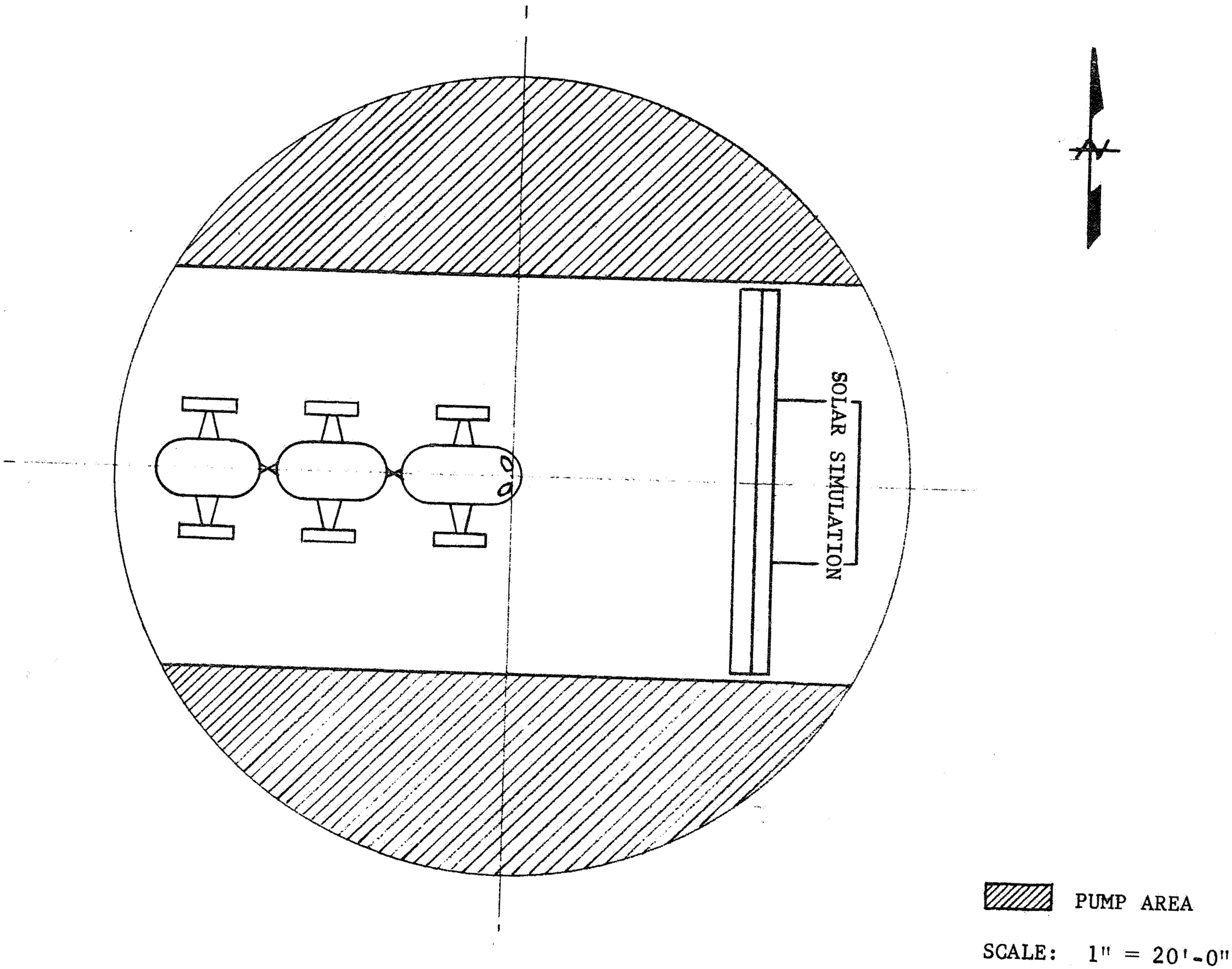


FIGURE V-5 SPACE PROPULSION FACILITY WORKING ENVELOPE

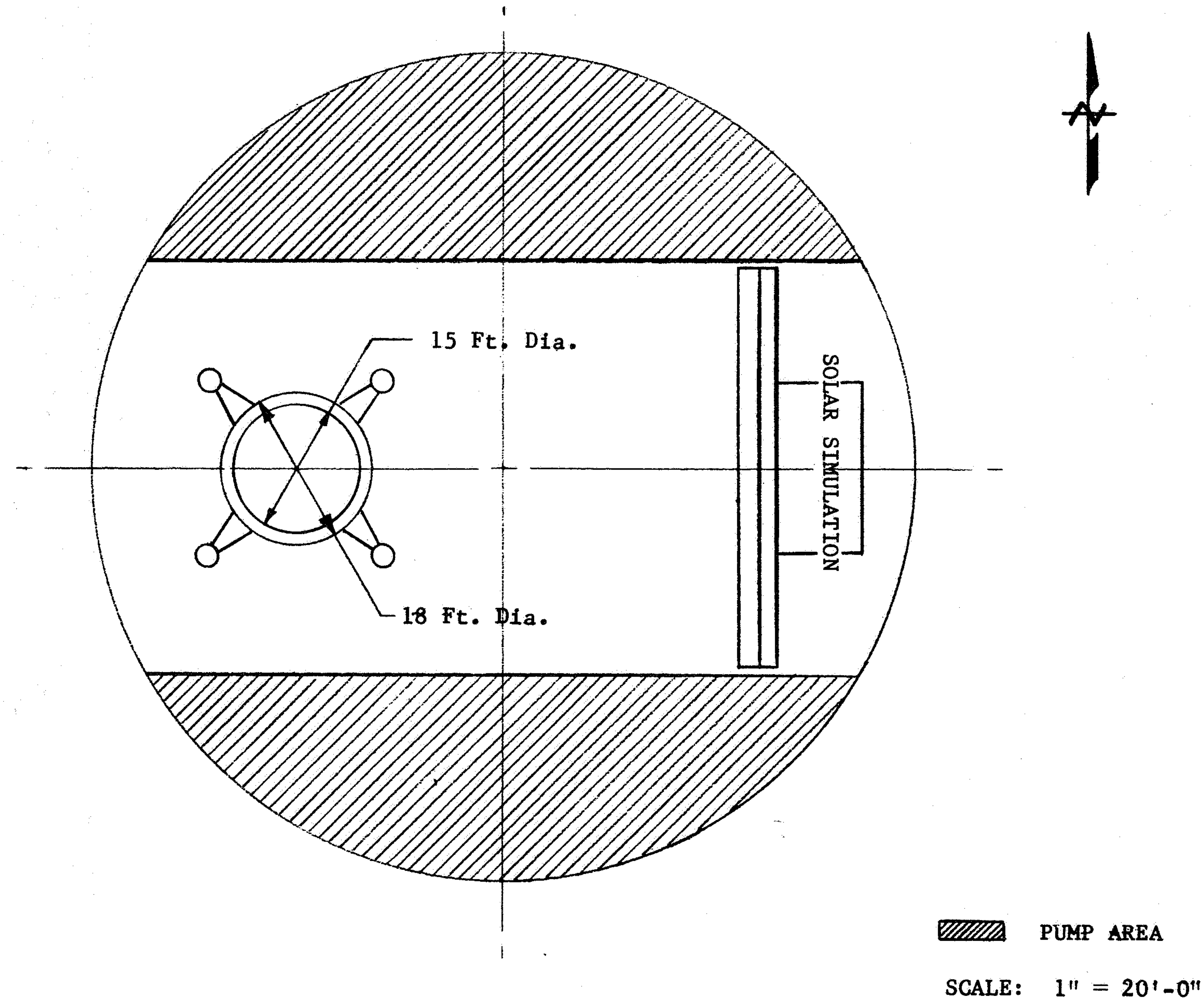
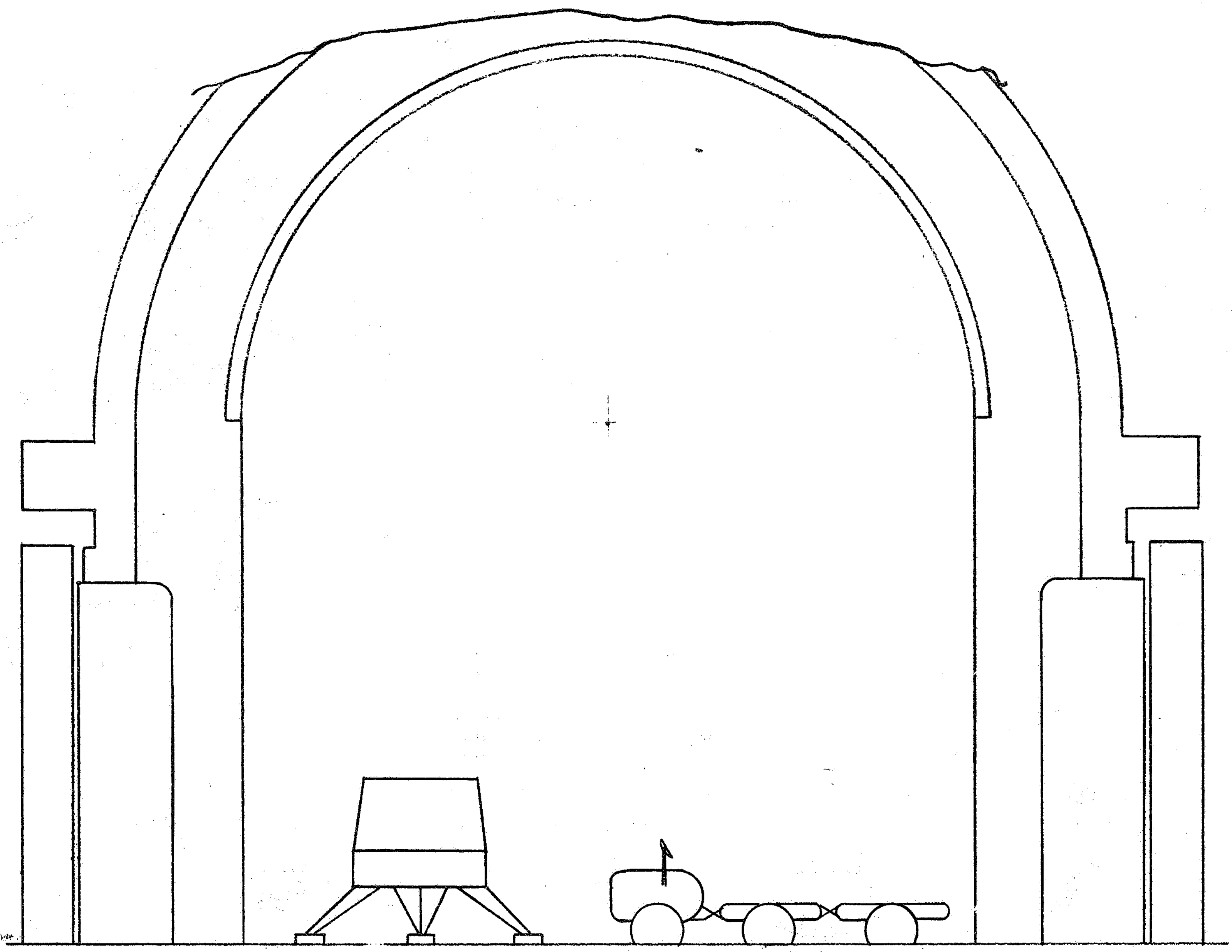
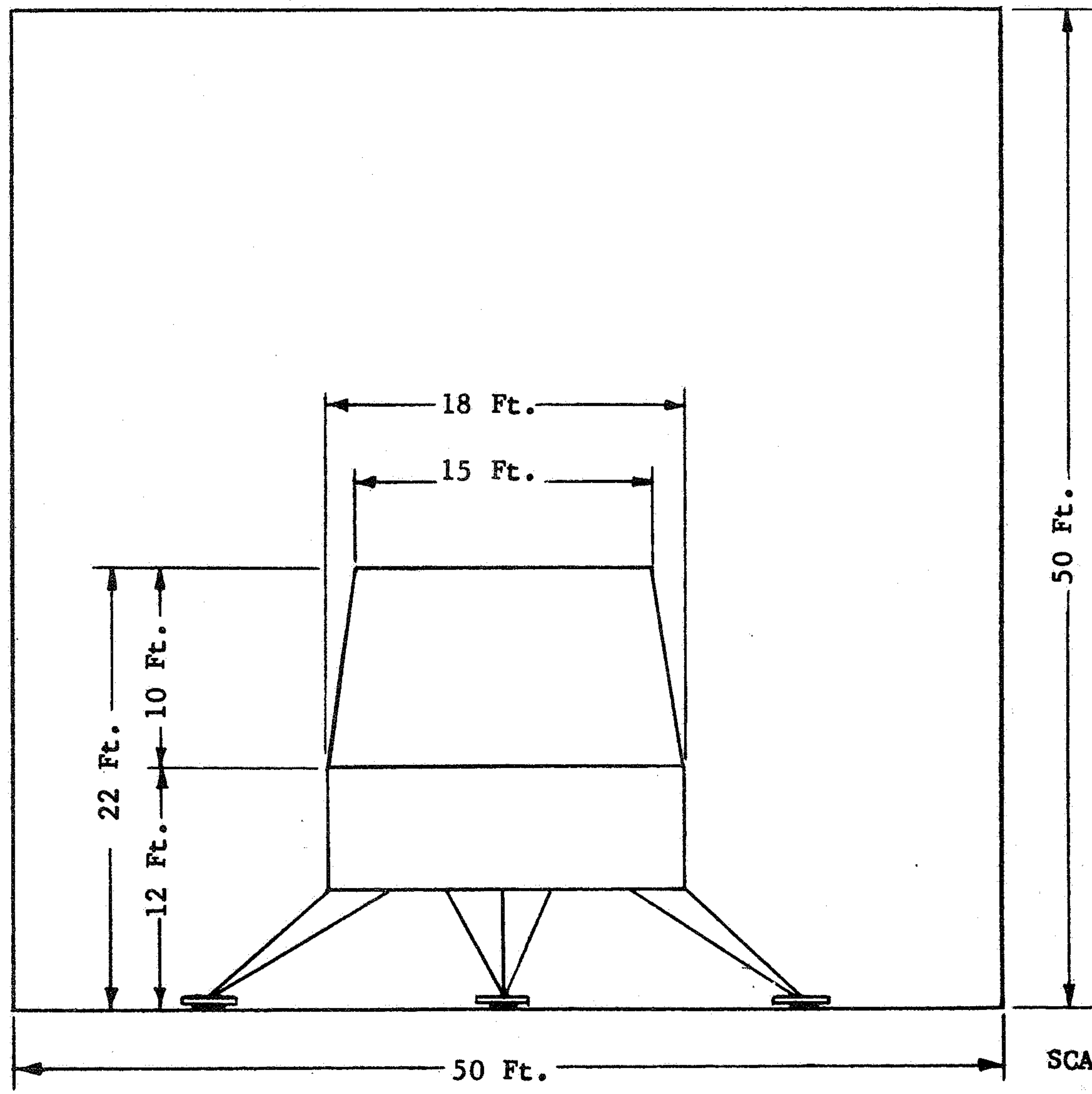


FIGURE V-6 SPACE PROPULSION FACILITY WORKING ENVELOPE



SCALE: 1" = 20'-0"

FIGURE V-7 SPACE PROPULSION FACILITY WORKING ENVELOPE



SCALE: 1" = 10'-0"

FIGURE V-8 SPACE PROPULSION FACILITY CHAMBER ENTRANCE SIZE

B. SPACE ENVIRONMENT SIMULATION FACILITY, CHAMBER A NASA MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

1. MAJOR SYSTEMS TESTING

Working Envelope

The NASA Manned Spacecraft Center Chamber A is the second largest chamber that will be available in this country in the near future. The lack of capability with respect to size for the Space Propulsion Facility is applicable to the Chamber A facility. Chamber A has a diameter of 65 feet containing a turntable of 45 feet diameter. This compares to a 100 foot diameter for the Space Propulsion Facility with a 50 foot by 100 foot working area. Figure V-9 illustrates the Chamber A floor area with an LRV in test position. The 46 foot long LRV can be accommodated on the 45 foot diameter turntable but there will be a slight overhang. To properly accommodate the LRV and maintain the 5 foot clearance to chamber surfaces, the LRV should not exceed 43 feet in length. The turntable is capable of supporting a centered test vehicle load of 150,000 pounds or an off-center load of 40,000 pounds. The turntable can therefore easily support and position the LRV weight of 6500 pounds without any modification. Although the floor area and turntable of Chamber A can accommodate the LRV, there remains a problem of positioning the LRV in satisfactory relationship with the solar simulation system. The distance between the LRV and the side sun solar source is 24 feet (minimum of 20 feet desirable) when the LRV is E-W or broadside to the solar source. This is adequate, but when the LRV is positioned in the N-S direction for illumination of the front or rear of the vehicle, the clearance between LRV and solar source is approximately 9 feet. This assumes the vehicle is positioned in the center of the turntable. If displaced to the far side of the chamber (without the 5 foot clearance from the wall) and still tested in the N-S position the clearance will still be less than 18 feet. The complete LRV cannot be tested for all horizontal solar orientations in Chamber A. One or two modules of the LRV could be tested at a time.

The LEM Truck may be tested in Chamber A without clearance difficulty as shown in Figure V-10. If positioned with a pair of landing legs in the N-S direction, the clearance between the solar source and the base of the leg will be 16 feet instead of the desired 20 feet but this should not be a serious problem. The turntable is capable of providing desired orientation to the solar source. Irradiation at one time of the entire surface of the LEM Truck or LRV is not possible, since the present side sun is only 13 feet wide; the future sun of 20 foot width will irradiate the shell of the LEM Truck but only a portion of the legs and only a module of the LRV.

Chamber Entrance

Entry to the chamber through the 40 foot diameter door is sufficient to permit entry of the ALSS equipment items.

Vacuum

Paragraph 8.3.1.1 of the Test Philosophy demands a vacuum of 10^{-8} torr with the chamber empty and 10^{-5} torr during testing. Based upon available pumping capacity, it can reasonably be assumed that this facility can achieve a vacuum of 10^{-8} torr with the chamber empty. However, it cannot maintain a vacuum of 10^{-5} torr during testing under all conceivable conditions because of the 12 lbs/day oxygen outgassing of the LRV and because of the oxygen and hydrogen leakage from the LEM Truck hydrogen oxygen fuel cell and fuel storage system.

Pumping Capacity

The pumping capacity of this facility is as follows:

Diffusion Pumps - $.35 \times 10^6$ liters/sec

100°K Condensibles (LN) - 300×10^6 liters/sec

20°K Condensibles (GHe) - 3×10^6 liters/sec

With careful selection of materials, cleaning and bakeout procedures, there is sufficient pumping capacity for the 100°K condensibles in the chamber heat sink walls. However, there is insufficient combined diffusion pump capacity and helium cryopanel capacity (combined 3.35×10^6 liters/sec) to account for the combined LRV oxygen leakage, the 10 KW hydrogen-oxygen fuel cell leakage, and miscellaneous leakage and outgassing (3.81×10^6 liters/sec). This determination is based on calculations in Chapter IV, Section F.

Heat Sink (100°K)

Liquid nitrogen cooling is provided in the chamber walls to produce a surface temperature of 100°K. Liquid nitrogen panels are coated to meet the requirement for high emissivity and low outgassing. To the maximum practical extent all surfaces in the chamber viewed by the vehicle should consist of heat sinks. The introduction of a 49 foot by 20 foot infrared array would seriously limit the heat sink view in addition to imposing a large heat load within the chamber. The liquid nitrogen refrigeration system presently has a heat sink capacity of 280 KW which is inadequate for the total maximum test load which has been determined to be as high as 490 KW. Addition of the 49 foot by 20 foot infrared panel would further increase the heat load.

Lunar Plane Temperature Control

Paragraph 8.3.1.7 of the Test Philosophy requires a simulated lunar plane surface temperature which is variable from +250°F to -250°F. The Chamber A lunar plane surface temperature can be controlled on a modular basis from -280°F to +260°F. If provision is made for programming this temperature control on a time temperature basis similar to Figure F-1 LUNAR SURFACE VARIATION DURING A LUNATION ON LUNAR CENTRAL MERIDIAN, the lunar temperature control should meet all of the demands of the Test Philosophy.

View Factor

In order to reproduce conditions approximating the lunar environment, it is necessary from thermal considerations that test articles have a view factor of a simulated lunar surface extending to the horizon and of deep space heat sink for a near full hemisphere. The limited lunar plane does not give a good approximation of the first condition.

Manrating

The manrating characteristics of this facility have been established as the criteria for manrating as specified in paragraph 8.3.1.11 of the Test Philosophy.

Sustained Operation

Paragraph 8.3.1.4 of the Test Philosophy requires a pumping system capable of operating continuously for a period of at least two weeks. This facility is designed to provide uninterrupted test environment for a period of 30 days. However, one serious problem in this connection will be the sustained leakage of 20°K condensibles which may result in excessive build-up on helium cryopanel surfaces. For example, in a two-week period the oxygen leakage from the LRV alone will result in a build-up of 168 pounds of liquid oxygen (based on 12 lb/day leakage rate).

10 KW Heat Load

Paragraph 8.3.1.4 of the Test Philosophy requires that the facility make provision for a radiation heat sink consisting of absorbing walls cooled to 100°K or lower, and capable of absorbing a 10 KW heat load from the test article. This facility is provided with a 280 KW capacity for the chamber heat sink. It has been estimated that the total maximum heat load is as follows:

Heat Loss (Pumping, piping, chamber)	87 KW
Solar Beam (Based on 20' diameter as largest load)	44 KW
Solar Simulator	----
IR Beam	----
IR Panel	----
Test Article Power	10 KW
Vehicle Exercise System	0-5 KW
Radiation from Lunar Plane @ +250°F	196 KW
TOTAL DEMAND	342 KW (1.17×10^6 BTU/Hr.)
TOTAL AVAILABLE	310 KW
SHORTAGE	32 KW

Chamber Clearance

Restricting the test objects to the 45 foot diameter lunar plane will maintain the 5 foot clearance between test articles and the chamber side surfaces.

Solar Simulation

The present solar simulation system provides initially for a 13 foot by 33 foot side sun and a 13 foot diameter top sun. Provision has been made for future enlargement of the side sun to irradiate an area 20 feet by 65 feet and the top sun to irradiate an area 20 feet in diameter. The increase in size of the top sun to 20 feet diameter will meet the test facility requirements, except that there is no provision to simulate the movement of the sun. Installation of a moving sun 20 feet in diameter is not feasible within the available space.

Infrared Radiation and Earthshine

Chamber A is not provided with infrared or earthshine simulation. Use of an array of tungsten lamps for supplementation of the solar spectrum simulating beam is a possibility. However, due to the size and configuration of the chamber,supplemental radiation to provide a 20 foot by 49 foot irradiated surface is not practical and would result in inadequate clearance between the test item and the array. In addition, the increased heat load and the decrement in wall view factor due to inclusion of the thermal array indicates that if infrared radiation or earthshine simulation is provided it should be on a local basis only as the test may warrant. Provision of a moving array or duplication or triplication of a fixed array would only aggravate the situation.

Test Object Orientation

A 45 foot diameter rotating table is included for orientation of the test object with respect to the solar simulation side sun.

Lunar Soil Simulant

There is no provision for lunar soil simulant in Chamber A. There is the capability of containing soil simulant to a total weight for the simulant and test items of 150,000 pounds. However, lack of sufficient area for trafficability studies precludes the need for lunar soil.

Surface Treatment

In the absence of a lunar soil simulant, a surface which has the thermal characteristics of the lunar surface would meet the principal test requirements other than means for trafficability studies. As stated above the size of the chamber precludes trafficability studies, therefore a surface treatment to simulate the thermal characteristics of the lunar surface could be provided.

Equipment Airlock

There is no equipment airlock on Chamber A. An airlock could be provided but due to the complexity of such an addition and the loss of utility and flexibility of the facility its incorporation is questionable.

Vehicle Exercise System

No vehicle exercise system is included in the present design. A system such as a dynamometer could be installed on the lunar plane for exercise of the LRV.

2. COMBINED SYSTEMS TESTING

Working Envelope

The working envelope is not of sufficient size to permit unloading the LRV and other payloads from the LEM Truck as required for Combined Systems Testing. Even if the LRV length were reduced to 20 feet, the LEM Truck legs removed and temporary supports provided to achieve a deployed LEM Truck dimension of 18 foot diameter in lieu of 33 feet, there is insufficient room on the working surface to satisfy the test requirements. The minimum required for Combined Systems Testing is 79 feet; a minimum deployment test requires 91 feet.

Chamber Entrance

Same as for Major Systems Testing.

Vacuum

The vacuum level requirements for Combined Systems Testing are essentially the same as for Major Systems Testing. The major problem will be additional oxygen and hydrogen leakage from two vehicle engine fuel systems instead of one (LEM Truck and LRV). It is estimated the LEM engine fuel system will introduce the following additional pumping load:

Oxygen leakage .21 x 10^6 liters/sec

Hydrogen leakage .40 x 10^6 liters/sec

Pumping Capacity

Pumping capacity will be insufficient for Combined Systems Testing for the reasons outlined in the above paragraph. It is estimated the following shortage of pumping capacity for 20°K condensibles would exist:

Total Requirement	4.21 x 10^6 liters/sec
Combined Helium Cryopanel and Diffusion Pumping	3.35 x 10^6 liters/sec
Additional Capacity Required	.86 x 10^6 liters/sec

Heat Sink (100°K)

Same as for Major Systems Testing

Lunar Plane Temperature Control

Same as for Major Systems Testing

View Factor

The problem of view factor is compounded in Combined Systems Testing. This is particularly true where positioning vehicles for certain solar simulation tests places the vehicle sides directly adjacent to the chamber walls.

Manrating

Same as for Major Systems Testing

Sustained Operation

Same as for Major Systems Testing

10 KW Heat Load

Same as for Major Systems Testing. There will be an increase of 2.5 KW in heat load associated with the LEM Truck power plant.

Chamber Clearance

Same as for Major Systems Testing

Solar Simulation

Same as for Major Systems Testing

Infrared Radiation and Earthshine

Same as for Major Systems Testing

Test Object Orientation

Same as for Major Systems Testing

Lunar Soil Simulant

Same as for Major Systems Testing

Surface Treatment

Same as for Major Systems Testing

Equipment Airlock

None is required for Combined Systems Testing

Vehicle Exercise System

Same as for Major Systems Testing

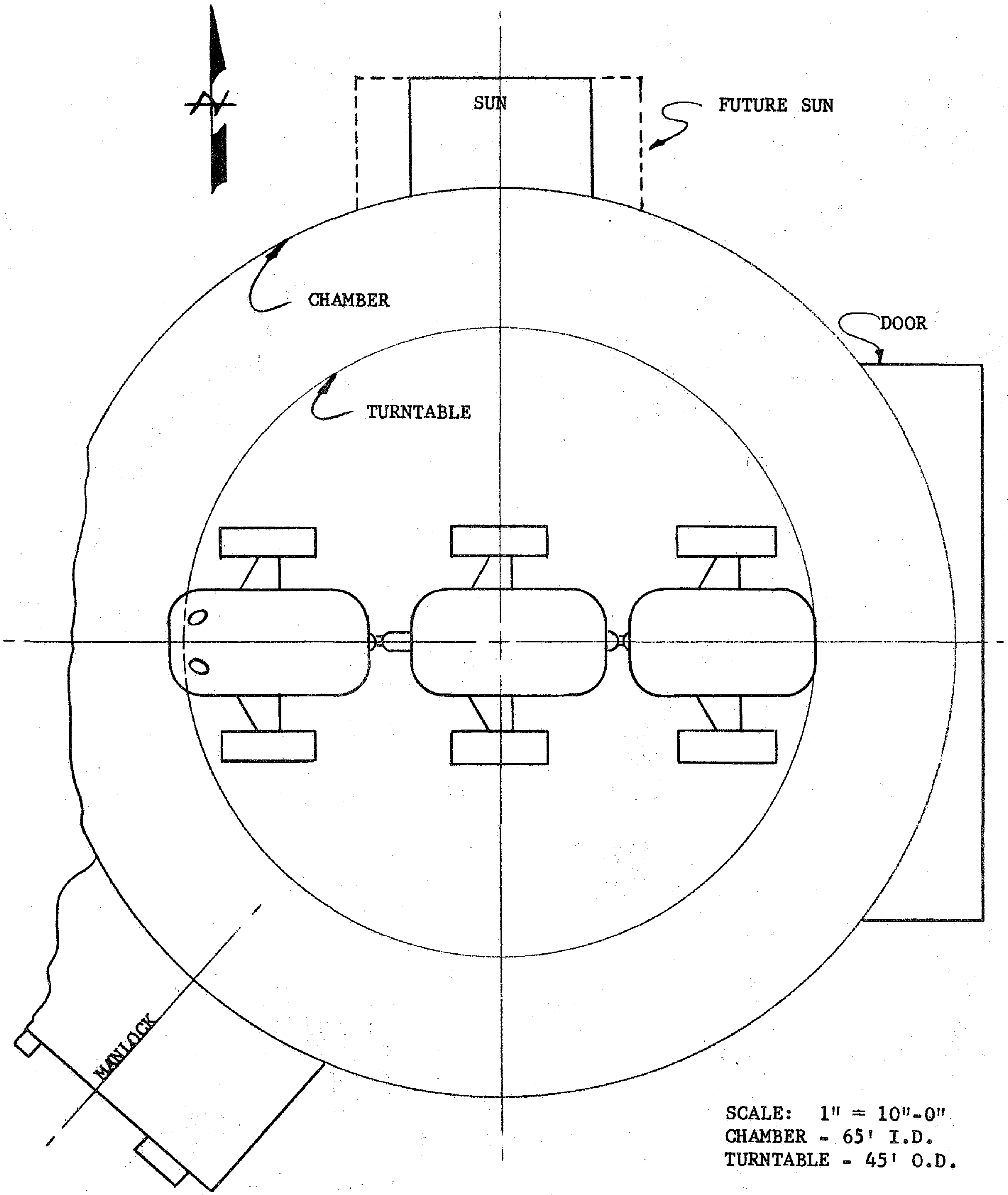


FIGURE V-9 AVAILABLE FLOOR AREA FOR CHAMBER "A"

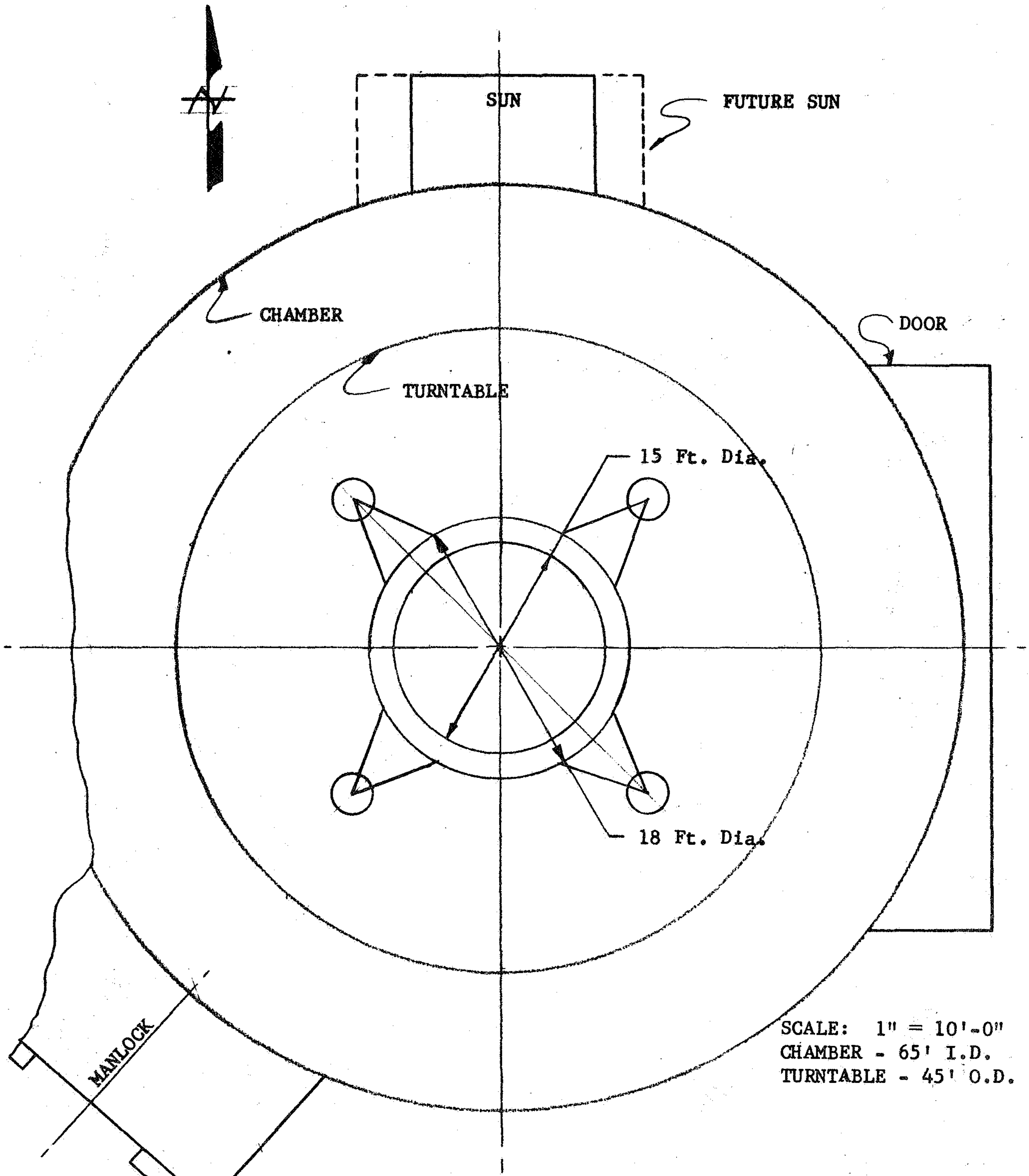


FIGURE V-10 AVAILABLE FLOOR AREA FOR CHAMBER "A"

C. AEROSPACE SYSTEMS ENVIRONMENTAL CHAMBER, MARK I, U.S. AIR FORCE ARNOLD ENGINEERING DEVELOPMENT CENTER, TULLAHOMA, TENNESSEE

The Mark I Chamber was designed primarily for testing of spacecraft. The chamber is 42 feet in diameter and 82 feet in height with work space dimensions of a nominal 35 feet in diameter by 65 feet in height. Providing for a 5 foot clearance between the test object and the cryopanel surfaces leaves only an area 25 feet in diameter in which to place the test object. This area is of sufficient size to allow placement of the LEM Truck without legs deployed but with payload, or the shelter/laboratory or the lunar flying vehicle. The working surface area is too small to permit individual testing of either the 17 foot wide by 46 foot long LRV or the LEM Truck with legs deployed. The criteria for test facilities for Combined Systems Testing requires an even larger facility in which to conduct unloading operations of the LRV and other payloads from the LEM Truck.

It is not reasonable to increase this facility in size to meet either the space demands for Major Systems Testing or Combined Systems Testing. Addition of an airlock would not provide the needed added space.

D. THERMAL VACUUM CHAMBERS OF THE SPACE ENVIRONMENT TEST FACILITY, GENERAL ELECTRIC VALLEY FORGE SPACE TECHNOLOGY CENTER, VALLEY FORGE, PENNSYLVANIA

The Thermal Vacuum Chambers consist of three separate 39 foot diameter spheres each having a work space equivalent to a 30 foot diameter spherical volume which could accommodate a test article approximately 21 feet in diameter by 30 feet high. They were designed specifically for testing spacecraft under thermal-vacuum conditions. The working envelope is of sufficient size to permit individual testing of the shelter/laboratory, lunar flying vehicle and the LEM Truck without legs deployed but with payload.

These chambers are too small to warrant further consideration for meeting the test facility requirements for either Major Systems Testing or Combined Systems Testing. Their size precludes testing of the 46 foot long LRV or the LEM Truck with legs deployed. The criteria for test facilities for Combined Systems Testing requires an even larger facility in which to conduct unloading operations of the LRV and other payloads from the LEM Truck.

Due to their size and configuration it is not reasonable to consider modifications to the chambers to meet the test facility requirements for either Major Systems Testing or Combined Systems Testing. Chambers of this type can be utilized, however, for tests of a lesser magnitude.

E. SOLAR-THERMAL-VACUUM CHAMBER OF THE SPACE ENVIRONMENT SIMULATION LABORATORY, GENERAL ELECTRIC VALLEY FORGE SPACE TECHNOLOGY CENTER, VALLEY FORGE, PENNSYLVANIA

The Solar-Thermal-Vacuum Chamber was designed for testing of spacecraft systems. The Chamber is 32 feet in diameter and 54 feet in height. The maximum size article that can be tested in the chamber is a 20 foot diameter sphere. The chamber size precludes its use for either Major Systems Testing or Combined Systems Testing. The size and configuration is such that it is not reasonable to consider modifications to the chamber to meet the test facility requirements. This chamber can be utilized, however, for smaller scale tests particularly where a good solar simulation source is needed.

F. OTHER CHAMBERS

The chambers evaluated in sections A through E represent the largest facilities of the type needed for testing the ALSS Payloads.

The Space Environment Simulator (Chamber 4) and Dynamic Test Chamber (Chamber 5) at Goddard Space Flight Center, which approximate the size of the General Electric Company 32 foot diameter by 54 foot high chamber, are not large enough to test the ALSS Payloads.

The Centaur Environmental Test Space Power Chamber (Chamber 9) which is a conversion of a section of an altitude wind tunnel is limited primarily by lack of headroom. This 30 foot diameter horizontal cylinder has therefore not been considered further.

The chamber (Chamber 10) originally considered by Marshall Space Flight Center for testing or portions of the Saturn is no longer proposed.

The three facilities at Langley Research Center (Chambers 11, 12 and 13) are too small for the ALSS Payloads. These facilities were not intended nor designed for such an application, nor is it reasonable to consider their modification for this program.

The Douglas Aircraft Company's 39 foot diameter chamber (Chamber 14) is similar in size to the three spheres at the General

Electric Space Center. The evaluation for these chambers in paragraph D is applicable to this chamber insofar as size is concerned. Although the capabilities of the Douglas' chamber varies from the General Electric chambers, it has been necessary to eliminate it for consideration based on physical size.

The Aerospace Systems Environmental Chamber, Mark IIA, (Chamber 8) has been under study for many months. Since construction has not been authorized a reliable forecast cannot be made as to its configuration or availability. However, based on the information contained in Appendix C its proposed size is adequate for the ALSS Payloads test facility requirements.

CHAPTER VI

CHAMBER MODIFICATIONS AND COST ESTIMATES

It was determined in this study that the Space Propulsion Facility, NASA Lewis Research Center, can meet the very minimum requirements for both Major Systems Testing and Combined Systems Testing if certain modifications are made. Such a course of action is economical and feasible if implemented immediately. However, this chamber, modified as proposed, would meet only the very minimum test requirements and would not resemble a chamber designed specifically for ALSS Payloads testing.

It was found impractical to modify the Space Environment Simulation Facility, Chamber A, NASA Manned Spacecraft Center, to meet the Combined Systems Testing requirements. Proposed modifications to Chamber A are described for Major Systems Testing.

Proposed modifications are based on adaptation of the chambers for ALSS Payloads testing without destroying the capabilities for which they were designed.

A. SPACE PROPULSION FACILITY, NASA LEWIS RESEARCH CENTER, PLUMBROOK STATION, OHIO

The proposed modifications to the Space Propulsion Facility are described below separately for Major Systems Testing and Combined Systems Testing and are shown on Drawings VI-1 through VI-7.

1. MAJOR SYSTEMS TESTING

Addition of Materials Lock

The equipment or materials lock shown on Drawing VI-7 is the minimum size for mating to the chamber. The lock has been shown as a movable lock for attachment to the inner chamber door. This feature is necessary to maintain the integrity of the nuclear radiation shielding provided by the large concrete door. The provision of a movable lock allows the use of the concrete door during nuclear system testing. Although the lock is classed as a movable lock, the peculiarity of the chamber precludes this in actuality. It would be necessary to provide sectionalized ring connectors and ring seals to seal the annular space between the chamber and chamber enclosure. The connectors would be flanged for bolted connection, however, to seal these sectional connectors positively, it would be necessary to weld beads along such flange edges. These beads would have to be cut out to remove the connectors. The necessity for mounting the lock proper on a movable platform with rail trucks results in a floor level 12 feet above the test chamber floor. This limits the weight handling capability through the lock.

The lock is provided with a liquid nitrogen cryopanel thermal shroud, diffusion pumps and a floor system containing nitrogen cryopanels.

Building Revisions

Building revisions are shown on Drawings VI-5 and VI-6. The movable materials lock would require space for storage of the lock when not in use. The addition of a new separate storage building 80 feet by 115 feet located east of the Assembly Area and connected by rail is shown on the revised Site Plan, Drawing VI-1.

The chamber building revisions consist of the following:

a. An increase of 20 feet in the diameter of the chamber enclosure.

b. The instrumentation and control area has been extended east-west by the additional 20 feet between test chamber enclosure main door pockets and extended north up to the office wing. In addition two additional floors have been added, making a total of four floors to this area. These are shown on Drawing VI-5.

c. The assembly area has been extended by one 24 foot bay to compensate for space lost when the equipment airlock is in place.

d. The cryogenics area has been extended to provide for a complete gaseous helium supply system for new chamber cryopanel installation.

Addition of Manrating Capability

Manrating for manned occupancy of the chamber requires a manlock, an emergency repressurization system, additional instrumentation and controls, gas storage facilities and associated piping. Possible locations for the manlock were considered including a movable manlock mated to one of the large doors, and the integration of the manlock with the decontamination chamber. However, a double manlock was added to the north side of the new chamber and connected to the Instrumentation and Control Area. A new sliding shield door of concrete was added to seal this penetration of the Test Enclosure.

A major consideration was the location of certain items for manrating which it was felt must be in the proximity of the manlocks. These items are as follows:

Environmental Control System (ECS) modules

Control room, consisting of control panels, bio-medical controls, TV, control console, and supporting equipment.

It is desirable that these instruments and controls be adjacent to or integrated with the existing instrumentation and control area. The location as shown on Drawing VI-5 was selected as the most feasible location with the least interferences.

Addition of Instrumentation for Test Objects

The existing instrumentation system and many of the controls in the present facility can be utilized. However, the complete requirements for monitoring of the LRV and LEM Truck structural, temperature, power, etc. impose increased requirements on the installation. It is estimated that a total of 1500 to 1800 additional data channels may be required.

Addition of Solar Simulation

For modification of this facility to meet the requirements of the Test Philosophy it is proposed to incorporate a moving sun assembly. This assembly, shown on Drawing VI-7, would consist of an array of 121 5 KW Xenon sealed lamp modules comprising a 20 foot diameter center solar simulation unit and 328 thermal radiation 1.0 KW Tungsten filament lamp modules. The Tungsten filament lamps would be mounted in two demountable wing banks on each side of the solar simulation unit providing an irradiated area of 20 feet high by 49 feet wide.

The center sun array would be contained in a gimbal ring mounted in an arched-frame gantry structure. The gimbal ring would be connected on each end to drive trucks which move the array around the arch frame gantry. The integrated solar and thermal lamp arrays would be capable of tracking a test object by gimbaling in the plane of the arch frame. Without the thermal lamp wing arrays the center solar array would be capable of also tracking objects transverse to the arch frame plane. The arch frame itself would be mounted and driven on a circular track around the chamber.

The electric power required to drive the moving sun units plus power required for the lamp modules would be furnished by a trolley type system commutated at the top of the arch frame. The control circuitry cables for the lamp module arrays would be reel mounted at the top of the arch frame. The coolant lines for the lamp modules would be flexible metal hose contained in reels mounted at the top of the arch frame.

The arch frame of the gantry would be composed of fabricated aluminum with titanium specials. The power and gear trains of drive units would be sealed. It is recognized that problem areas exist in such a concept. Of these the requirement for decontamination of the unit after nuclear testing in the chamber presents the most difficult problem.

Consideration was given to the use of three fixed solar arrays and a rotating turntable in lieu of this moving sun concept. However, cost of triplicating the solar simulation and thermal arrays and the cost of a turntable would be very great and yet not provide the capability to track test objects on the lunar plane.

Nitrogen Refrigeration

The following modifications are considered essential to meet the demands for nitrogen refrigeration:

Basic chamber LN heat sink	1512 KW
Diffusion pump baffles	150 KW
Equipment airlock cryopanel heat sink	10 KW
Additional baffles for diffusion pumps 18 @ 4.7 KW each	85 KW
TOTAL DEMAND	1757 KW
Available	1100 KW
ADDITIONAL REQUIRED	657 KW
LN Boil Off Required (based on 60% increase)	203.2 gpm
Available Rate	127.0 gpm
ADDITIONAL BOIL OFF REQUIRED	76.2 gpm

The total refrigeration demand is 60% greater than the present capability. This would require the following additional equipment:

GN_2/LN subcooler	30,000 lbs/hr Boil Off capacity
Increase in LN cryopanel capacity	60%
Total tons of LN refrigerant per day @ 203.2 gpm	986 T/day
Per 14 days	13,800 T

Vacuum Pumping

The following modifications are considered essential to meet the requirements for additional 20°K condensible pumping in the basic chamber:

Required 20°K condensibles	3.81×10^6 liters/sec
Available pumping	1.5×10^6 liters/sec
ADDITIONAL REQUIRED	2.31×10^6 liters/sec
Present diffusion pumping	1.5×10^6 liters/sec
Additional diffusion pumps (12)	$.42 \times 10^6$ liters/sec
Addition of 1180 sq ft of panel area and 2-1.75 KW He refrigeration units	3.0×10^6 liters/sec
TOTAL AVAILABLE W/MODIFICATION	4.92×10^6 liters/sec
RESERVE CAPACITY	1.11×10^6 liters/sec

This reserve is considered desirable since it provides additional panel area for condensate build-up over a two week period. Furthermore, it permits adaptation of a design used in an existing facility.

He refrigeration units	2-1.75 KW
Pumping rate	1700 lbs/hr
Leakage rate	6 lbs/hr

The following modifications are considered desirable to meet the requirements for pumping 100°K condensibles and non-condensibles in the materials lock.

Panels LN 100°K condensibles (see LN refrigeration)	9.4×10^6 liters/sec
6 - 54 inch diffusion pumps	$.21 \times 10^6$ liters/sec
TOTAL PUMPING (100°K condensibles and non-condensibles)	9.61×10^6 liters/sec

Lunar Plane Temperature Control

The temperature at any point on the lunar surface may be a function of a number of variables. These are primarily as follows:

Heat input from simulated solar radiation.

Heat radiation to 100°K heat sink.

Thermal conductivity of the surface.

Shadowing from the test article.

Conduction to or from the test article.

Radiation to or from the test article.

Controlled (programmed) heat input.

Controlled (programmed) heat removal.

Under natural conditions the vehicle moves across the lunar surface and does not appreciably affect the surface temperature due to shadowing, conduction, or radiation. However, the sustained position of the test article in the chamber will have a decided surface temperature effect due to these factors. Furthermore, there is the additional problem of a moving sun which changes shadow positions and the unit area intensity of the lunar flux. For these reasons provision must be made for the following on the lunar plane:

(1) GN cooling flow rate control on a unit area basis in the chamber floor.

(2) Controlled electrical strip heating on a unit area basis in the chamber floor.

(3) An integrated programmed controller for GN_2 control valves and electrical strip heat elements.

(4) Provision for vertical 10' wall thermal panels, heated by electrical heating elements and programmed to simulate the lunar plane. These must be integrated with liquid nitrogen cryopanels.

(5) Surface and subsurface high thermal conductivity to assure homogeneous surface temperature between control elements.

Chamber Size

A properly proportioned view of the heat absorbing walls, simulating deep space, and of the test chamber floor, simulating the lunar surface, is an important test element in evaluating vehicle thermal balance. There are a number of factors which will affect reasonable simulation of this condition in this chamber. These are as follows:

a. The diffusion pump floor well area.

b. The solar panel.

c. Proximity to the chamber walls.

d. Major protuberances in the chamber wall, view ports, TV cameras, miscellaneous equipage.

Since it is not feasible to extend the lunar plane across the diffusion pump wells there is no practical way to fully correct this condition. The provision for additional thermal panels to better the view factor and careful positioning of Major Systems test vehicles would minimize this deficiency. However, other requirements of the Test Philosophy necessitate extensive modifications to the test chamber and result in a reduction in the working area. If such modifications were made, the size of the test chamber and test chamber enclosure should be increased thereby clearing the floor of diffusion pumps and providing use of the entire chamber floor.

Vehicle Exercise System

No provision is made in the design for a vehicle exercise system. Utilizing a dynamometer concept no appreciable modification of the chamber is required for incorporation of the VES. The dynamometers would be bolted into the floor and the necessary electrical and coolant lines brought through appropriate chamber penetrations.

2. COMBINED SYSTEMS TESTING

Building Revisions

The building revisions are the same as for Major Systems Testing, except that there is no requirement for an equipment airlock, hence no storage space is needed for the airlock and no addition to the building is required to compensate for the loss of space.

Addition of Manrating Capability

The modification is the same as for Major Systems Testing.

Addition of Instrumentation for Test Objects

Additional instrumentation is required for the combinations of vehicles in lieu of single vehicles as for Major Systems Testing.

Addition of Solar Simulation

The modification is the same as for Major Systems Testing.

Nitrogen Refrigeration

The following modifications are considered essential to meet the demands for nitrogen refrigeration:

Basic chamber LN heat sink	1512 KW
Diffusion pump baffles	150 KW
Additional baffles for diffusion pumps 12 @ 4.7 KW	56 KW
TOTAL DEMAND	1718 KW
Available	1100 KW
ADDITIONAL REQUIRED	618 KW

LN Boil Off Required (based on 56% increase)	198 gpm
Available Rate	127 gpm
ADDITIONAL BOIL OFF REQUIRED	71 gpm

This requirement is less than for Major Systems Testing since an equipment airlock is not required for Combined Systems Testing. Since total refrigeration is 56% greater than the available rate a major modification would be required. This would necessitate the following additional equipment:

GN_2/LN subcooler	28,000 lbs/hr Boil Off capacity
Increase in LN cryopanel capacity	56%
Total tons of LN refrigerant per day @ 198 gpm	965 T/day
Per 14 days	13,500 T

Vacuum Pumping

The modification is the same as for Major Systems Testing except that there is no requirement for additional pumping in the equipment airlock.

Lunar Plane Temperature Control

The modification is the same as for Major Systems Testing.

Chamber Size

The discussion for Major Systems Testing is also applicable to Combined Systems Testing. To provide a better view factor for the vehicle combinations requires an increase in shell diameter. It would be desirable to increase the shell diameter to 141 feet minimum to achieve required clear diameter inside the cryopanels of 130 feet. This would require increasing also the concrete test enclosure structure a like amount. However, this is economically infeasible. A minimum increase of 10 feet is proposed in the diameter of the chamber to permit installation inside of thermal shrouds and cryopanels and allow a clear diameter of 100 feet. Relocation of the diffusion pumps to the chamber walls would permit use of the entire chamber floor. The relocation of the diffusion pumps to the annular space would necessitate adding 5 feet to the existing 15 feet for an annulus width of 20 feet. The test chamber would be increased to 110 feet inside diameter and the test chamber enclosure would be increased to 150 feet inside diameter.

Addition of Dynamometer System

The modification is the same as for Major Systems Testing.

3. COST ESTIMATES

The estimated costs for the modifications to the Space Propulsion Facility are presented below. These estimates are based on concept data only; they have not been prepared on detailed design. Construction contract, applicable design and development costs are included; construction impact costs as a result of suspension of work are not included. Costs for redesign have been based only on those portions of the facility affected by modification. Development costs have been included for items in the solar simulation system.

Major Systems Testing

a.	Addition of Materials Lock	$1,841,000
b.	Addition of Materials Lock Storage Building	363,000
c.	Building Expansion and Modification including test chamber enclosure, test chamber, assembly area, instrumentation and control area, and cryogenic area.	4,078,000
d.	Manrating	1,498,000
e.	Instrumentation and Control Equipment	1,850,000
f.	Solar Simulation	8,625,000
g.	Nitrogen Refrigeration System	3,580,000
h.	Vacuum Pumping System	2,760,000
i.	Lunar Plane Temperature Control	1,248,000
j.	Dynamometer System	780,000
	TOTAL	$26,623,000

Combined Systems Testing

a.	Building Expansion and Modification including test chamber enclosure, test chamber, instrumentation and control area, and cryogenic area	$3,922,000
b.	Manrating	1,498,000
c.	Instrumentation and Control Equipment	2,215,000

d.	Solar Simulation	8,625,000
e.	Nitrogen Refrigeration System	3,430,000
f.	Vacuum Pumping System	2,580,000
g.	Lunar Plane Temperature Control	1,248,000
h.	Dynamometer System	780,000
	TOTAL	$24,298,000

B. SPACE ENVIRONMENT SIMULATION FACILITY, CHAMBER A, NASA MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

The modifications to the Space Environment Simulation Chamber are described below for Major Systems Testing and are shown on Drawings VI-8 and VI-9.

1. MAJOR SYSTEMS TESTING

Addition of Equipment Airlock

The equipment or materials lock would be a permanent addition to chamber A. It is shown in detail on Drawing VI-9. Because of limited assembly area space between Chamber A and Chamber B a concept of lock and chamber door operation which would provide some remaining assembly area was adopted. A ring collar would be attached to the existing chamber door opening extending the door flange out to where a new sliding door could operate into a door pocket in the new lock. A removable lock door would be provided which will be lifted by the existing overhead traveling crane and deposited in a cradle while the lock is open. The lock would be provided with a liquid nitrogen cryopanel thermal shroud system, six diffusion pumps and a floor system containing nitrogen cryopanels.

Installation of this lock would require a new piled reinforced concrete foundation well under the lock and the door pocket. It would require relocation under the door pocket well of an existing utility trench and associated utilities. It would require reconstruction of several building column foundations.

Building Revisions

The present entry door into the assembly area would require relocation as shown on the plan, Drawing VI-8.

The existing Chamber B head laydown platform would require relocation to provide for increased assembly area between the new equipment airlock and Chamber B. Therefore, the existing structure would require extension of two bays beyond Chamber B and the head laydown platform relocated into the area provided by these two new bays.

Addition of Instrumentation for Test Objects

The existing instrumentation equipment is adequate for this testing program insofar as reduction and collection equipment and data channels are concerned. Acquisition means such as sensors and control room equipment would be increased for this program's particular test equipment.

Addition of Solar Simulation

It is proposed to increase the side-sun of Chamber A by addition of the necessary carbon-arc lamp modules to provide a bottom sun of 20 feet by 20 feet. The existing top-sun of Chamber A would be increased by addition of the necessary lamp modules to provide a 20 foot diameter top sun.

Nitrogen Refrigeration

The following modifications are considered essential to meet the demands for nitrogen refrigeration:

Basic chamber LN heat sink	342 KW
Equipment airlock cryopanel heat sink	10 KW
TOTAL DEMAND	352 KW
Available	310 KW
ADDITIONAL REQUIRED	42 KW
LN Boil off required (based on 13.5% increase)	46 gpm
Available rate	40 gpm
ADDITIONAL BOIL OFF	6 gpm

Since the total refrigeration demand is only 13.5% greater than the existing requirement, only minor modification is required. This would consist of increasing the capacity of the GN_2/LN subcooler by 15%.

Total tons of LN refrigerant per day @ 46 gpm	223 T/day
Per 14 days	3120 T

Vacuum Pumping

The following modifications are considered essential to meet the requirements for additional 20°K condensible pumping in the basic chamber:

Required 20°K condensibles	3.81×10^6 liters/sec
Available pumping	3.35×10^6 liters/sec
ADDITIONAL REQUIRED	$.46 \times 10^6$ liters/sec

Present diffusion pumps	$.35 \times 10^6$ liters/sec
Present He cryopanel pumping	3.0×10^6 liters/sec
Addition of 590 sq ft of panel area and 1.75 KW He refrigeration	1.5×10^6 liters/sec
TOTAL AVAILABLE w/MODIFICATION	4.85×10^6 liters/sec
RESERVE CAPACITY	1.04×10^6 liters/sec

This reserve is considered desirable since it provides additional refrigeration and panel area for condensate buildup over a two week period. Furthermore it would permit expansion of the facility on a modular basis.

Present refrigeration units	2-1.75 KW
Present pumping rate He	1700 lbs/hr
Present leakage @ .35% of flow	6 lbs/hr
Additional refrigeration units	1-1.75 KW
Additional pumping rate He	850 lbs/hr
Additional leakage	3 lbs/hr
TOTAL REFRIGERATION UNITS w/MOD.	3-1.75 KW
TOTAL PUMPING w/MOD	2550 lbs/hr
TOTAL LEAKAGE w/MOD	9 lbs/hr

Lunar Plane Temperature Control

Provision must be made for the following in the lunar plane:

GN cooling flow rate control on a unit area basis in the chamber floor.

Controlled electrical strip heating on a unit area basis for the chamber floor.

An integrated programmed controller for GN control valves and electrical strip heating elements.

Vertical 10' high wall thermal panels, heated by electrical heating elements and programmed to simulate the lunar plane. These could be integrated with liquid nitrogen cryopanels.

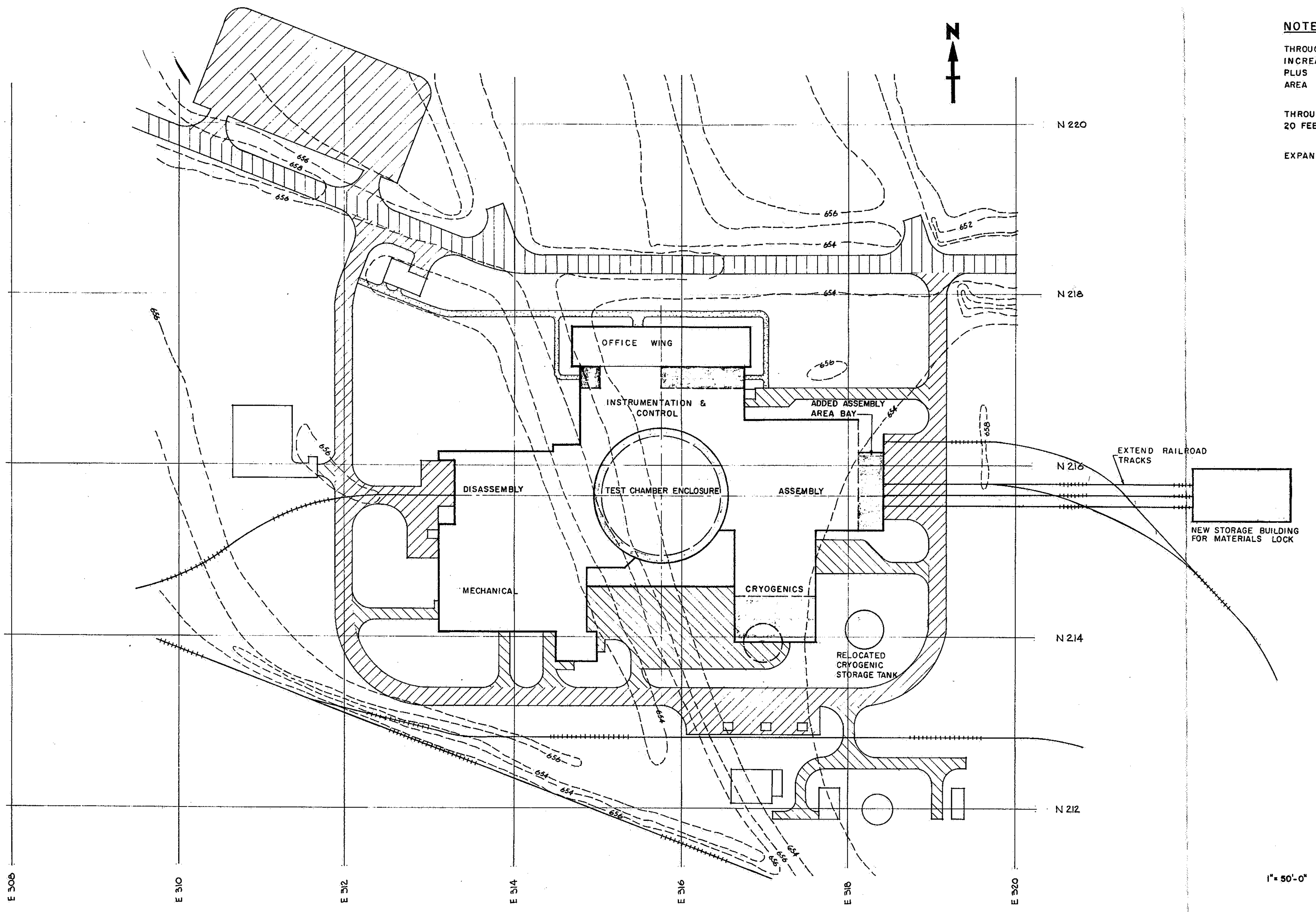
Surface and subsurface high thermal conductivity to assure homogeneous surface temperature between control elements.

2. COST ESTIMATES

The estimated costs for the modifications to Chamber A and the facility are presented below. The estimates represent construction contract and engineering design costs. Construction impact costs are not included.

Major Systems Testing

a.	Addition of materials lock	\$3,093,000
b.	Building revisions	362,000
c.	Chamber modifications (Incl solar simulation, LN cryopanels, cryopumping, piping, instrumentation, lunar plane temperature control, dyanamometer system)	3,350,000
d.	Refrigeration equipment	890,000



NOTES:

EAST-WEST PLAN DIMENSION OF BUILDING THROUGH CENTERLINE OF TEST CHAMBER HAS BEEN INCREASED 20 FEET THROUGH TEST ENCLOSURE PLUS ONE 24 FEET BAY ADDITION TO THE ASSEMBLY AREA (44 FEET TOTAL)

NORTH-SOUTH PLAN DIMENSION OF BUILDING THROUGH ℄ OF TEST CHAMBER HAS BEEN INCREASED 20 FEET THROUGH TEST ENCLOSURE

SHADED AREAS INDICATE PRIMARY BUILDING EXPANSIONS

SITE PLAN

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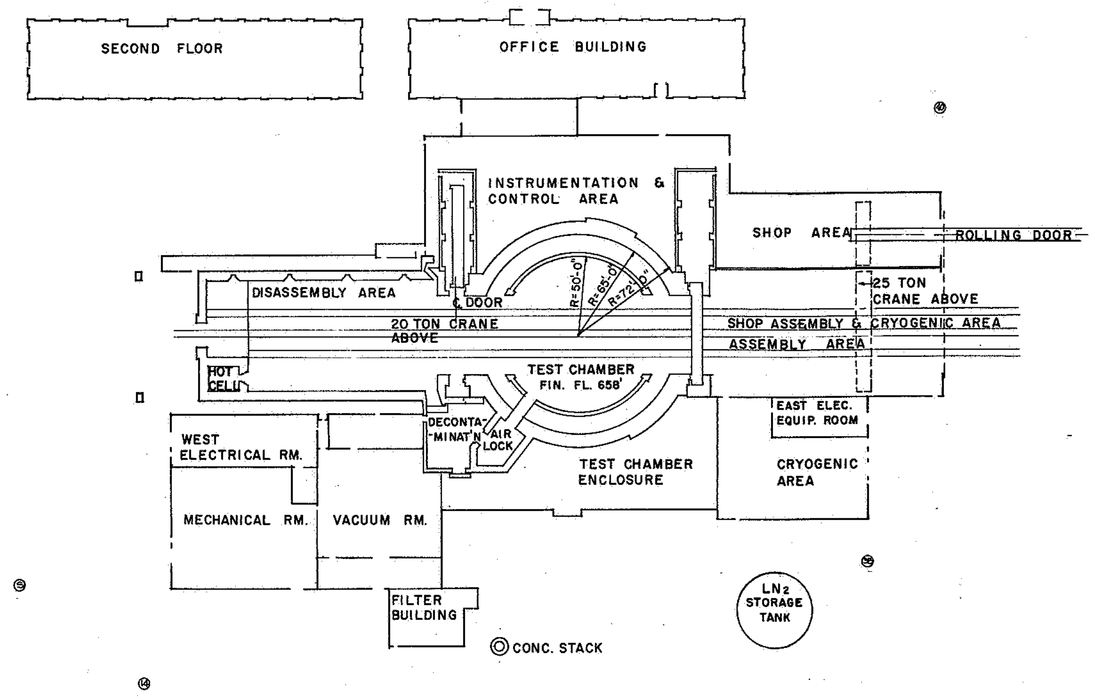
SPACE PROPULSION FACILITY
PLUM BROOK STATION

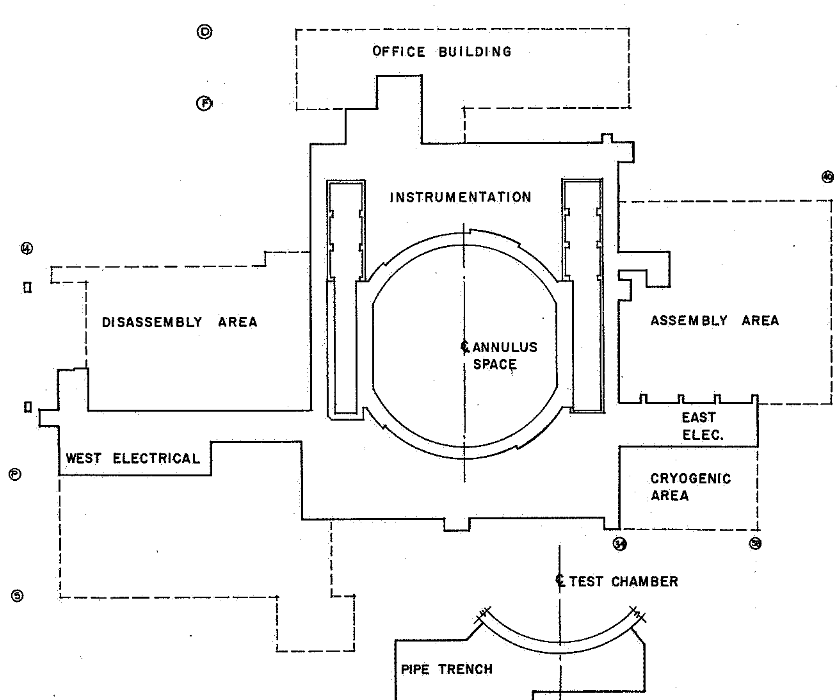
MODIFICATIONS
SITE PLAN

15 DEC. 1964 DRAWING NO VI-1



GROUND FLOOR PLAN

ELEV. 658.00



FIRST BASEMENT PLAN ELEV. 645.00

SUB-BASEMENT PLAN

OUTLINE SPECIFICATIONS

OFFICE BUILDING	
FOUNDATIONS	REINFORCED CONCRETE
FRAMING	STEEL
1ST FLOOR	CONCRETE SLAB ON COMPACTED ROCK FILL
2ND FLOOR	CONCRETE SLAB ON METAL DECK
ROOF	BUILT-UP ROOFING ON RIGID INSULATION ON METAL DECK ON STEEL ROOF FRAMING
EXTERIOR WALL	PRECAST CONCRETE WALL PANELS - BRICK SPANDREL
WINDOWS	ALUMINUM
SUSPENDED CEILINGS	ACOUSTICAL TILE FINISH
SHOP, ASSEMBLY AND CRYOGENIC AREA	
FOUNDATIONS	REINFORCED CONCRETE
FRAMING	STEEL
FLOOR	CONCRETE SLAB ON COMPACTED ROCK FILL
ROOF	BUILT-UP ROOFING ON RIGID INSULATION ON METAL DECK ON TRUSSED STEEL ROOF FRAMING
EXTERIOR WALL	INSULATED METALLIC SIDING
EXTERIOR WALL LIGHT PANELS	PLASTIC SIDING
EXTERIOR ASSEMBLY ROOM DOOR	STEEL, HORIZONTAL-SLIDING 50' w x 55'h
ASSEMBLY AREA CRANE	OVERHEAD TRAVELING BRIDGE CRANE
MECHANICAL, ELECTRICAL AND VACUUM AREAS	
FOUNDATIONS	REINFORCED CONCRETE
BASEMENT	REINFORCED CONCRETE
FLOOR	CONCRETE SLAB ON COMPACTED ROCK FILL
ROOF	BUILT-UP ROOFING/RIGID INSULATION/METAL DECKING ON STEEL ROOF FRAMING
EXTERIOR WALL	INSULATED METALLIC SIDING
EXTERIOR WALL LIGHT PANELS	PLASTIC SIDING
INTERIOR WALLS	CONCRETE MASONRY UNITS
INSTRUMENTATION AND CONTROL AREA	
FOUNDATIONS	REINFORCED CONCRETE
BASEMENT-EXTERIOR WALLS & FLOOR	REINFORCED CONCRETE
INTERIOR BASEMENT COLUMNS	STEEL
REMOVABLE FIRST FLOOR	STEEL FLOOR DECKING ON STEEL FLOOR FRAMING
ROOF	BUILT-UP ROOFING/1" RIGID INSULATION/METAL ON STEEL ROOF FRAMING
EXTERIOR WALL	INSULATED METALLIC SIDING
TEST CHAMBER ENCLOSURE	
TEST CHAMBER PILES	REINFORCED CONCRETE TENSION PILES
TEST CHAMBER ENCLOSURE SHELL	REINFORCED CONCRETE, STEEL PLATE MEMBRANE, BORATED CONCRETE INNER SURFACES, THERMAL INSULATION INNER SURFACE, EXTERIOR DOME SURFACE w/PROTECTIVE COATING, TRENCHES, CHAMBER PIERS, COVERS AND HATCHES
ENCLOSURE MAIN DOORS	REINFORCED CONCRETE, BORATED CONCRETE FACING, THERMAL INSULATION, ALUMINUM SHEET FACING, COMPLETE WITH DOOR SLIDING MECHANISMS, DOOR LOCKING MECHANISMS, SEALS, SHIELD BLOCKS, PLATFORMS, ETC. COMPLETE
TEST CHAMBER	
SHELL & PLATFORM	ALUMINUM PLATE AND STRUCTURAL SHAPE
MAIN DOORS	ALUMINUM-SLIDING COMPLETE WITH AUTOMATIC SEAL MECHANISM
ENVIRONMENTAL CONTROL EQUIPMENT	
VACUUM	MECHANICAL PUMPING-DIFFUSION PUMPING
THERMAL	NITROGEN COOLED PANELS ON EXTERIOR OF CHAMBER SHELL

GRAPHIC SCALE

1" = 40'-0" 40' 20' 0 40' 80'

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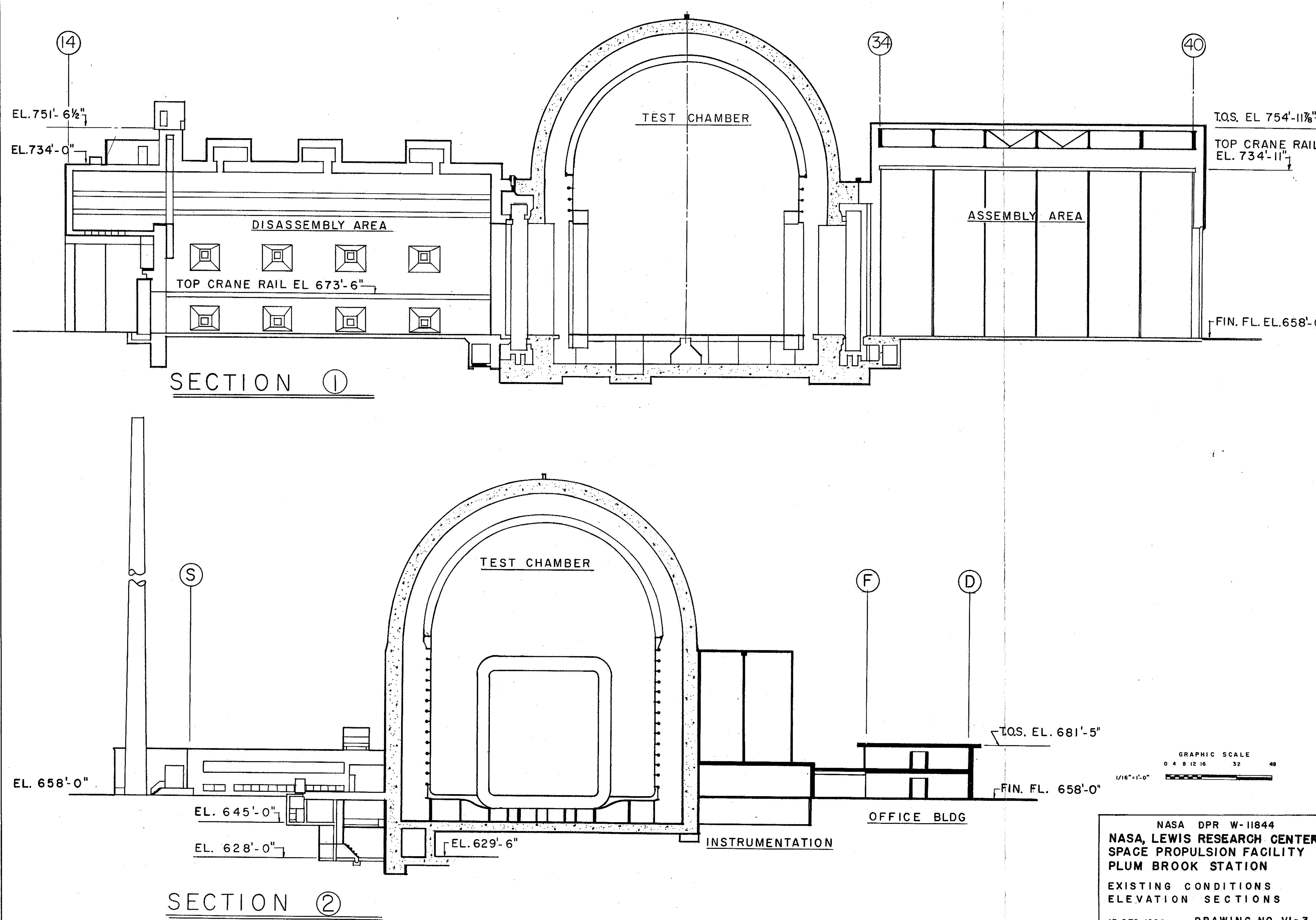
EXISTING CONDITIONS
PLANS-OUTLINE SPECIFICATIONS

15 DEC. 1964 DRAWING NO VI-2



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SPACE PROPULSION FACILITY
PLUM BROOK STATION

EXISTING CONDITIONS
ELEVATION SECTIONS

15 DEC. 1964 DRAWING NO VI-3

MODIFICATIONS
SPACE PROPULSION FACILITY, PLUMBROOK

CHAMBER

INCREASE CHAMBER DIAMETER FROM 100'-0" TO 110'-0". CHAMBER HEIGHT TO BE MAINTAINED. USE ALL ALUMINUM CONSTRUCTION.

CHAMBER FLOOR

PROVIDE NEW CHAMBER FLOOR SYSTEM. NEW FLOOR TO SUPPORT A 300 POUND PER SQUARE FOOT LIVE LOAD, TWIN I-BEAM GIRDERS TO PROVIDE SUPPORT TO RAILS UPON WHICH THE TRAVELING MOVING-SUN ARCH STRUCTURE OPERATES, AND CHAMBER PROPER. USE ALL ALUMINUM AND STAINLESS STEEL CONSTRUCTION.

CRYOPANELS

1. PROVIDE CRYOPANELS INSIDE THE CHAMBER ABOVE THE SOLAR PLANE. LIQUID NITROGEN CRYOPANELS SHALL BE UTILIZED FOR A THERMAL SHROUD AND SHIELDS AND GASEOUS HELIUM CRYOPANELS FOR CRYOPUMPING.

2. PROVIDE LIQUID NITROGEN CRYOPANELS IN THE CHAMBER FLOOR DECK PLUS IN THE 10 FOOT PERIPHERY FLIP-UP PANELS. PROVIDE ELECTRICAL RESISTANCE-TYPE HEATING FACILITY IN THE CHAMBER FLOOR DECK PLUS IN 10 FOOT PERIPHERY FLIP-UP PANELS.

DIFFUSION PUMPS

PROVIDE REMOVAL OF ALL DIFFUSION PUMPS FROM FLOOR STRUCTURE OF CHAMBER AND RELOCATION ON THE CHAMBER SIDEWALL IN LOCATION SHOWN ON PLANS. TOTAL OF FORTY-FOUR (44) 54-INCH DIAMETER DIFFUSION PUMPS TO BE INSTALLED COMPLETE WITH COLD TRAPS AND VACUUM CLOSURE VALVES.

PERSONNEL LOCK

PROVIDE A DOUBLE PERSONNEL LOCK AT THE SOLAR PLANE LEVEL CONNECTING THE CHAMBER TO THE BIO-MEDICAL FACILITIES DIRECTLY TO THE NORTH OF THE CHAMBER.

CHAMBER DOOR RELOCATION

REDUCE THE CHAMBER MAIN DOOR IN WIDTH TO 40 FEET AND RELOCATE BOTH DOORS TO THE NORTH SIDE OF THE CHAMBER.

MATERIALS LOCK

PROVIDE A MATERIALS LOCK LOCATED IN ASSEMBLY AREA AND CONNECTED TO THE EAST CHAMBER DOOR THROUGH THE EAST TEST ENCLOSURE DOOR PORTAL. THE MATERIALS LOCK SHALL IN ESSENCE BE CLASSIFIED AS MOVABLE. PROVIDE THE NECESSARY RING CONNECTORS AND SEAL RINGS REQUIRED TO CONNECT THE LOCK TO THE CHAMBER DOOR PORTAL, TO THE TEST ENCLOSURE DOOR PORTAL AND ALSO TO SEAL THE ANNULUS SPACE BETWEEN CHAMBER-ENCLOSURE AND THE ASSEMBLY AREA. THE MATERIALS LOCK SHALL PROVIDE CHAMBER ENTRY AND LOCK-ENTRY DOORS, LIQUID NITROGEN LOCK HEAT-SINK CRYOPANELS, SIX (6) 32-INCH DIFFUSION PUMPS MOUNTED ON THE LOCK AND A RAIL-OPERATED LOCK-SUPPORT PLATFORM.

MOVABLE SUN SYSTEM

PROVIDE MOVABLE SUN SYSTEM IN THE CHAMBER. SUN SYSTEM MAJOR COMPONENTS CONSIST OF 20-FOOT DIAMETER CENTER BANK SYSTEM OF SOLAR SIMULATION LAMP MODULES WITH WING BANKS OF INFRA-RED LAMP MODULES, TRAVELING ARCH-FRAME (GANTRY), ELECTRIC POWER SUPPLY, LAMP COOLANT SUPPLY AND LAMP CONTROL CIRCUITRY. THE INTEGRATED SOLAR SIMULATION LAMP MODULE BANK SHALL BE MOUNTED IN A GIMBAL RING WHICH PROVIDES THE BANK THE CAPABILITY TO IRRADIATE TEST UNITS IN CENTER OF SOLAR PLANE FROM ANY POSITION OF THE SUN IN THE PLANE OF THE ARCH FRAME. THE SOLAR SIMULATION LAMP MODULE BANK WITHOUT IR WING BANKS SHALL ALSO BE GIMBALED FOR MOVEMENT TRANSVERSE TO THE PLANE OF THE ARCH FRAME. THE MOVING SUN UNIT SHALL TRAVEL IN THE ARCH FRAME FROM SUN-RISE POSITION TO SUNSET POSITION. PROVIDE A 25-TON CAPACITY TRAVELING HOIST PLATFORM TO BE LOCATED IN THE ARCH FRAME BUT NOT TO BE OPERATED CONCURRENTLY WITH THE SUN-UNIT. PROVIDE ELECTRIC POWER, LAMP MODULE CIRCUIT CONTROL CABLES AND LAMP MODULE COOLANT SUPPLY THROUGH THE TOP OF THE CHAMBER. ELECTRIC POWER SUPPLY SHALL BE PROVIDED IN THE ARCH FRAME FROM A TROLLEY SYSTEM COMMUTATED AND SEALED AT THE TOP OF THE ARCH FRAME. PROVIDE A SOLAR BANK METHANOL COOLING SYSTEM SUPPLY THROUGH FLEXIBLE METAL HOSE FROM REELS AT THE TOP OF THE ARCH FRAME. PROVIDE LAMP MODULE CIRCUIT CONTROL CABLES FROM REELS AT THE TOP OF THE ARCH FRAME.

NORMAL REPRESSURIZATION SYSTEM

PROVIDE A TEST CHAMBER NORMAL REPRESSURIZATION SYSTEM, COMPLETE. THIS SHALL RAISE THE CHAMBER FROM FULL VACUUM CONDITION TO 6 PSIA WITHIN 30 MINUTES OR TO 14.7 PSIA WITHIN 3 HOURS AS REQUIRED.

EMERGENCY REPRESSURIZATION SYSTEM

PROVIDE A TEST CHAMBER EMERGENCY REPRESSURIZATION SYSTEM, COMPLETE. THIS SHALL RAISE THE CHAMBER TOTAL PRESSURE FROM FULL VACUUM CONDITION TO 6 PSIA AND OXYGEN PARTIAL PRESSURE TO 4.5 PSIA WITHIN 30 SECONDS OR TO A TOTAL PRESSURE OF 14.7 PSIA WITHIN 60 SECONDS. THE REPRESSURIZATION SHALL BE ACCOMPLISHED BY INTRODUCING INTO THE CHAMBER, IN ORDER, NITROGEN, OXYGEN AND ATMOSPHERIC PRESSURE AIR. PROVIDE SHOCK AND ACOUSTIC LEVEL ATTENUATION. PROVIDE CHAMBER AIR REHEAT.

ENVIRONMENTAL CONTROL SYSTEM

PROVIDE AN ENVIRONMENTAL CONTROL SYSTEM WHICH WILL FURNISH ALL BASIC LIFE SUPPORT REQUIREMENTS TO PERSONNEL WEARING PRESSURE SUITS AND SUBJECT TO AN EXTERNAL PRESSURE RANGE OF 14.7 PSIA DOWN TO SUBSTANTIALLY 0 PSIA. BASICALLY THIS SHALL BE AN ADEQUATE SUPPLY OF BREATHING OXYGEN CONDITIONED FOR PRESSURE, RELATIVE HUMIDITY AND TEMPERATURE.

CHAMBER ENCLOSURE

INCREASE CHAMBER ENCLOSURE INSIDE DIAMETER FROM 130 FEET TO 150 FEET. THIS PROVIDES FOR INCREASING THE ANNULUS SPACE FROM 15 FEET WIDTH TO 20 FEET WIDTH. MAINTAIN THE SAME ANNULAR SPACE ON SIDES AND OVER SPHERICAL TOP OF TEST CHAMBER.

INSTRUMENTATION AND CONTROL AREAS

INCREASE INSTRUMENTATION AND CONTROL AREAS AS SHOWN ON THE PLAN. THIS PROVIDES FOR EXTENDING IN PLAN TO THE OFFICE WING ON THE NORTH AND BETWEEN THE ENCLOSURE DOOR POCKETS ON EAST AND WEST SIDES AND PROVIDES FOR TWO ADDITIONAL FLOORS. THIS AREA PROVIDES FOR INCREASED TEST CONTROL AND MONITORING. AN ADDITIONAL 1800 DATA CHANNELS SHALL BE PROVIDED WHICH BRINGS THE FACILITY TOTAL TO 2100 CHANNELS. PROVIDE ALL DATA HANDLING SYSTEM EQUIPMENT REQUIRED FOR THE ACQUISITION, INTEGRATION AND CORRELATION OF ANALOG DATA FROM VEHICLE SYSTEMS, VEHICLE STRUCTURAL INSTRUMENTATION, FACILITY INSTRUMENTATION AND BIO-MEDICAL INSTRUMENTATION. EQUIPMENT SHALL INCLUDE MULTIPLEXERS, ANALOG-TO-DIGITAL CONVERTERS, DIGITAL COMPUTER, TAPE STORAGE, TAPE READOUT, VISUAL PRINT-OUT, PATCH-BOARDS, RACKS, AND DISPLAY CONSOLES. THE DIGITAL COMPUTER SHALL INCLUDE CENTRAL PROCESSOR, DIRECT INPUT/OUTPUT CHANNELS, BUFFER INPUT/OUTPUT CHANNELS, PRIORITY INTERRUPT, MAGNETIC TAPE UNITS, TYPEWRITERS, TAPE PUNCH AND READER. AN INSTRUMENT REPAIR AREA SHALL BE INCLUDED.

ASSEMBLY AREA

INCREASE ASSEMBLY AREA BY TWO BAY LENGTHS TO THE EAST. PROVIDE SLIDING DOOR SIZE CAPABLE OF ALLOWING ENTRY OF MATERIALS LOCK FROM NEW STORAGE SHED ON RAIL TRAVELING PLATFORM.

BIOMEDICAL FACILITIES

PROVIDE BIOMEDICAL FACILITY INCLUDING ASTRONAUT SUIT REQUIREMENTS, PHYSIOLOGICAL MONITORING PREPARATION, DISPENSARY AND EMERGENCY MAJOR SURGERY FACILITY. THIS FACILITY SHALL BE ON THE CHAMBER SOLAR PLANE LEVEL (GROUND FLOOR) IN THE INSTRUMENTATION AND CONTROL AREAS.

CRYOGENIC AND REFRIGERATION AREA

INCREASE CRYOGENIC AND REFRIGERATION AREA TO PROVIDE NECESSARY HELIUM SYSTEM REFRIGERATOR UNITS, CONTROL EQUIPMENT, PUMPS, ETC. PROVIDE FOR NITROGEN SYSTEM INCREASED EQUIPMENT CAPACITY TO INCLUDE COMPRESSION EQUIPMENT, CONTROL EQUIPMENT, PUMPS, ETC. PROVIDE REQUIRED ADDITIONAL STORAGE TANKS OR CAPACITY FOR HELIUM AND NITROGEN.

ELECTRICAL AREA

INCREASE ELECTRICAL AREA TO INCLUDE INCREASED ELECTRICAL POWER REQUIREMENTS AND CONTROL EQUIPMENT.

MATERIALS LOCK STORAGE BUILDING

PROVIDE A STEEL FRAMED BUILDING COVERED WITH METAL INSULATED SANDWICH SIDING AND ROOFING AND WITH LARGE SLIDING DOOR FOR STORAGE OF THE MATERIALS LOCK AND DOOR RING CONNECTOR AND SEAL SEGMENTS.

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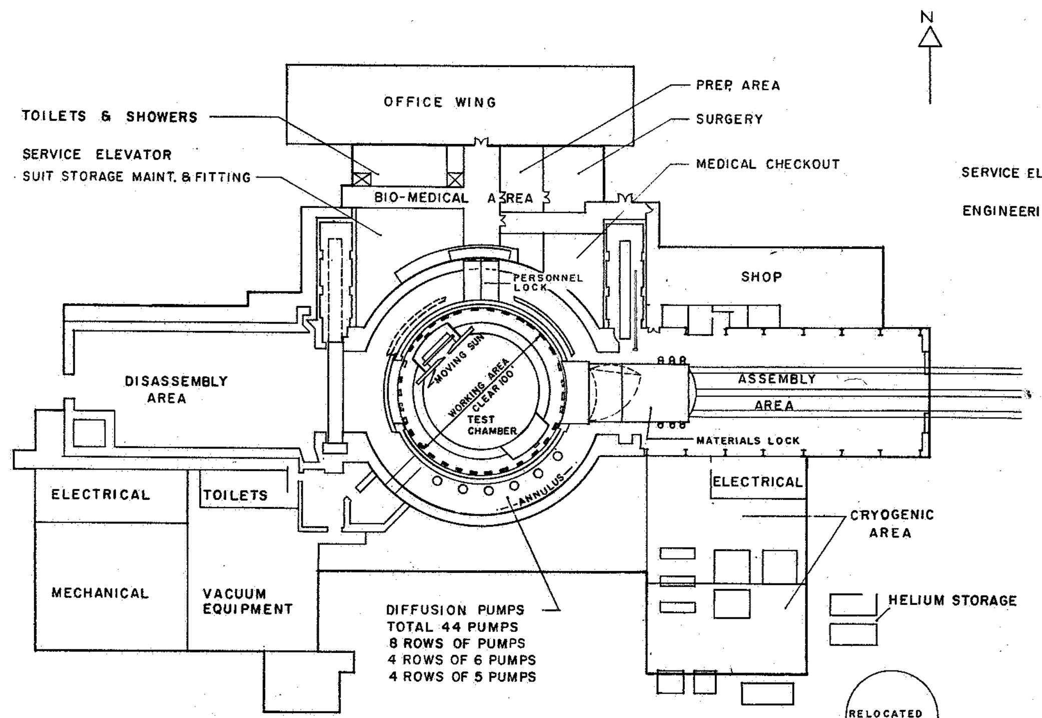
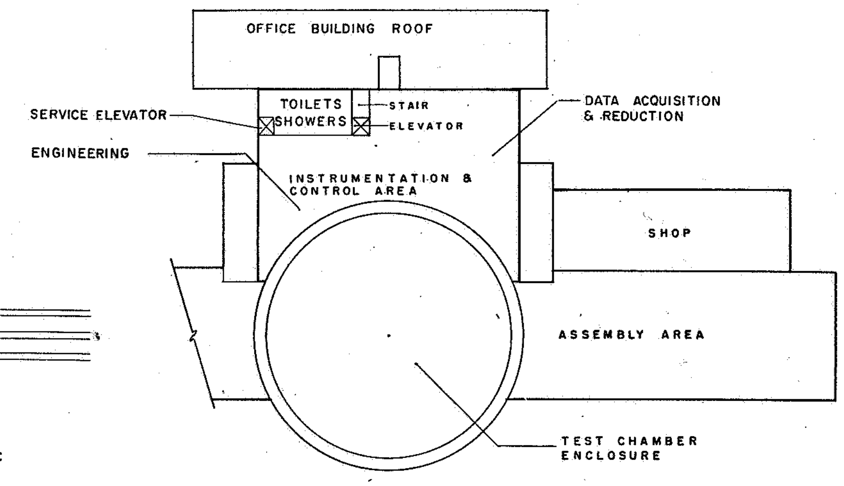
MODIFICATIONS
OUTLINE SPECIFICATIONS

15 DEC. 1964 DRAWING NO. VI-4



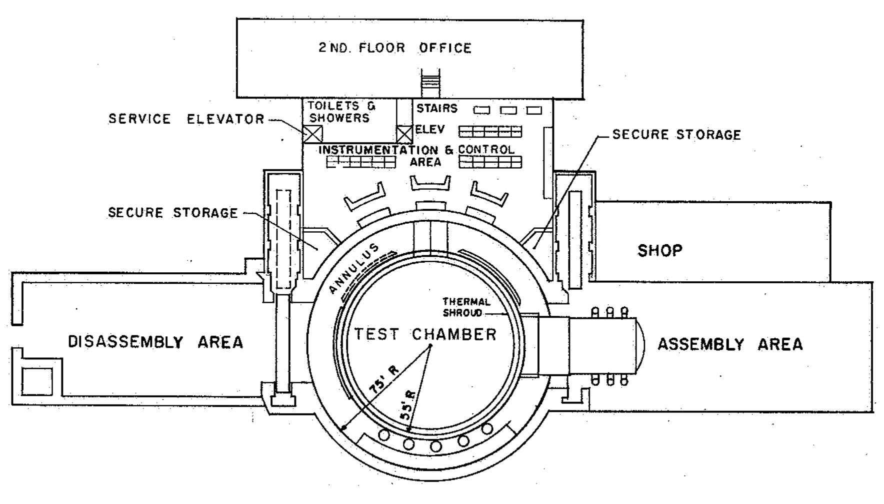
GROUND FLOOR PLAN

ELEV. 658'-0"



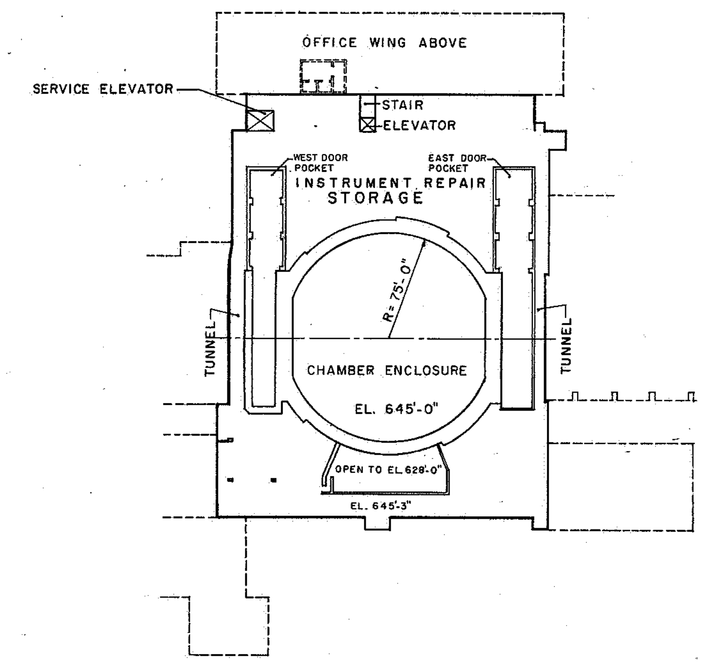
THIRD FLOOR PLAN

ELEV. 690'-0"



SECOND FLOOR PLAN

ELEV. 674'-0"



FIRST BASEMENT PLAN

ELEV. 645'-0"

GRAPHIC SCALE
0 10 20 40 80 120
1" = 40'

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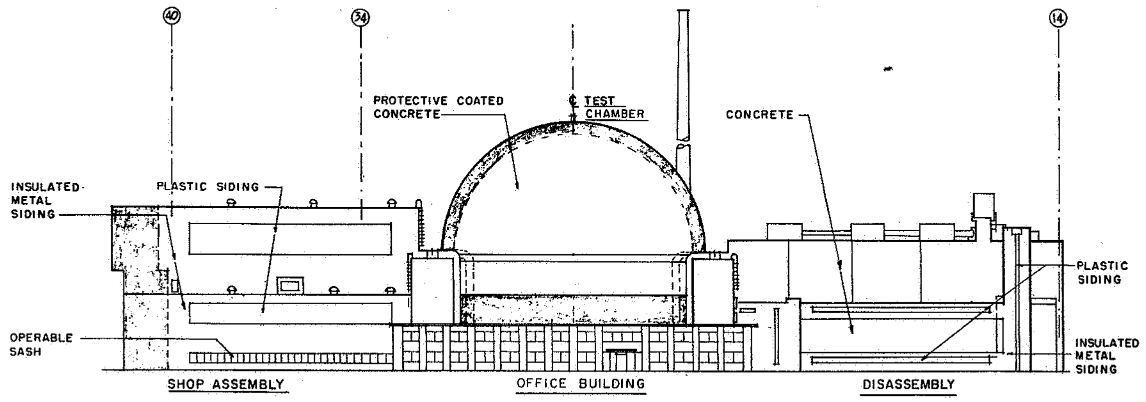
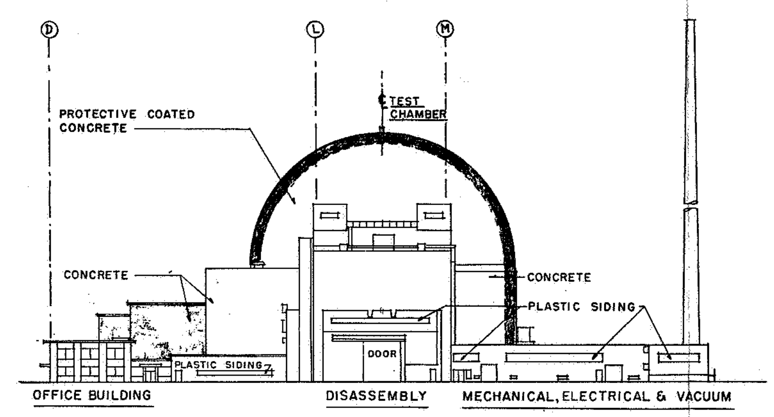
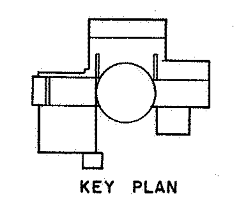
PLUM BROOK STATION
MODIFICATIONS
PLANS
15 DEC. 1964 DRAWING NO VI-5

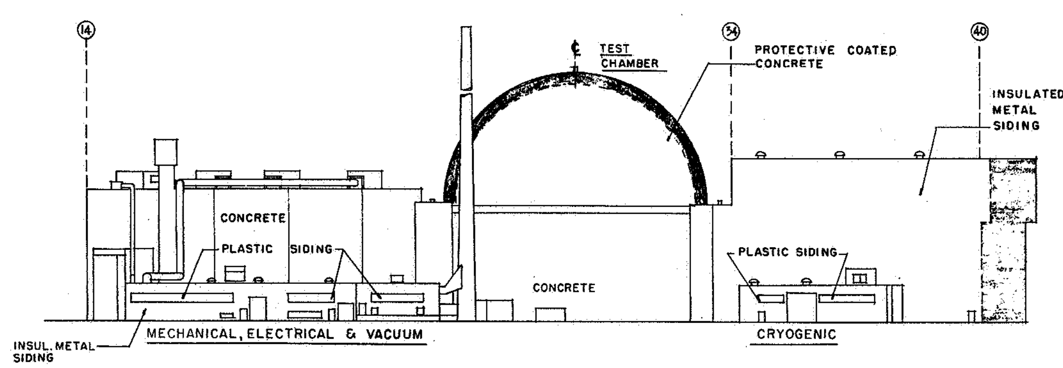


NORTH ELEVATION

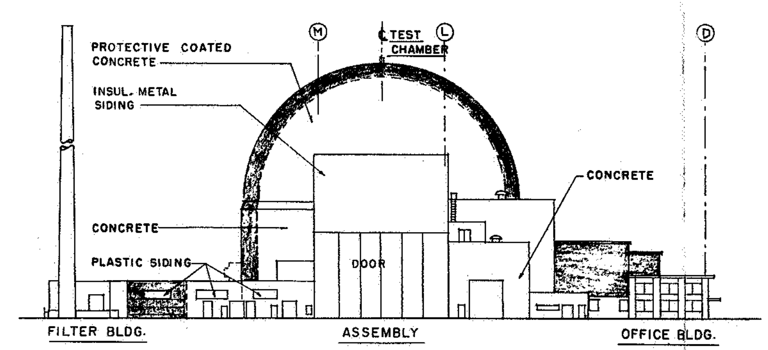


WEST ELEVATION





SOUTH ELEVATION



EAST ELEVATION

GRAPHIC SCALE
40' 20' 0 40' 80'
1" = 40'-0"

NOTE: SHADED AREAS INDICATE PRIMARY BUILDING EXPANSIONS

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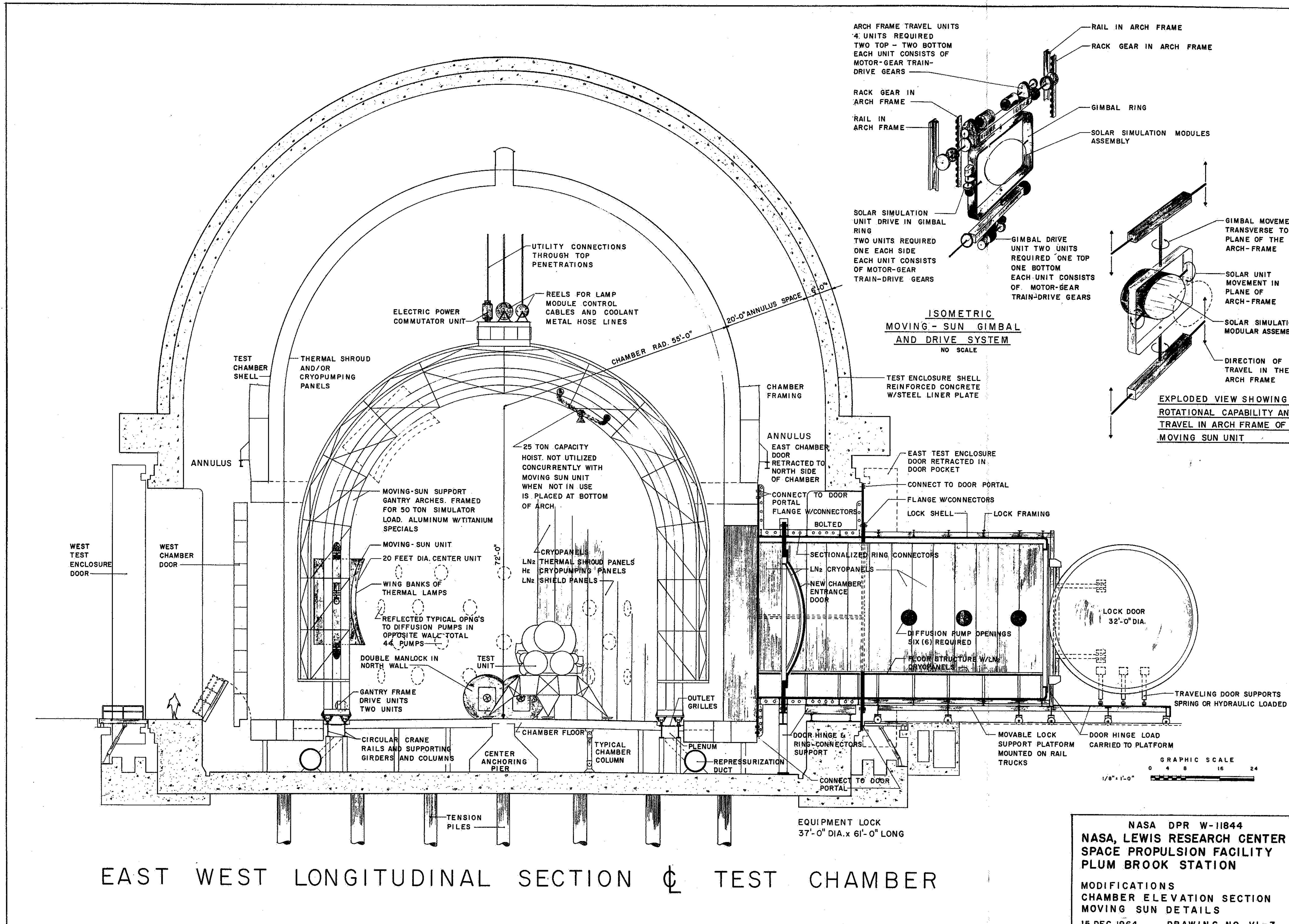
MODIFICATIONS
ELEVATIONS

15 DEC. 1964 DRAWING NO VI-6


ARCH FRAME TRAVEL UNITS
4 UNITS REQUIRED
TWO TOP - TWO BOTTOM
EACH UNIT CONSISTS OF
MOTOR-GEAR TRAIN-
DRIVE GEARS
RAIL IN ARCH FRAME
RACK GEAR IN ARCH FRAME
RACK GEAR IN
ARCH FRAME
RAIL IN
ARCH FRAME
GIMBAL RING
SOLAR SIMULATION MODULES
ASSEMBLY
SOLAR SIMULATION
UNIT DRIVE IN GIMBAL
RING
TWO UNITS REQUIRED
ONE EACH SIDE
EACH UNIT CONSISTS
OF MOTOR-GEAR
TRAIN-DRIVE GEARS
GIMBAL DRIVE
UNIT TWO UNITS
REQUIRED ONE TOP
ONE BOTTOM
EACH UNIT CONSISTS
OF MOTOR-GEAR
TRAIN-DRIVE GEARS
ISOMETRIC
MOVING - SUN GIMBAL
AND DRIVE SYSTEM
NO SCALE
GIMBAL MOVEMENT
TRANSVERSE TO
PLANE OF THE
ARCH-FRAME
SOLAR UNIT
MOVEMENT IN
PLANE OF
ARCH-FRAME
SOLAR SIMULATION
MODULAR ASSEMBLY
DIRECTION OF
TRAVEL IN THE
ARCH FRAME
EXPLODED VIEW SHOWING
ROTATIONAL CAPABILITY AND
TRAVEL IN ARCH FRAME OF
MOVING SUN UNIT
UTILITY CONNECTIONS
THROUGH TOP
PENETRATIONS
REELS FOR LAMP
MODULE CONTROL
CABLES AND COOLANT
METAL HOSE LINES
ELECTRIC POWER
COMMUTATOR UNIT
20'-0" ANNULUS SPACE 5'-0"
CHAMBER RAD. 55'-0"
TEST
CHAMBER
SHELL
THERMAL SHROUD
AND/OR
CRYOPUMPING
PANELS
CHAMBER
FRAMING
TEST ENCLOSURE SHELL
REINFORCED CONCRETE
W/STEEL LINER PLATE
ANNULUS
25 TON CAPACITY
HOIST. NOT UTILIZED
CONCURRENTLY WITH
MOVING SUN UNIT
WHEN NOT IN USE
IS PLACED AT BOTTOM
OF ARCH
ANNULUS
EAST CHAMBER
DOOR
RETRACTED TO
NORTH SIDE
OF CHAMBER
EAST TEST ENCLOSURE
DOOR RETRACTED IN
DOOR POCKET
CONNECT TO DOOR PORTAL
FLANGE W/CONNECTORS
LOCK SHELL
LOCK FRAMING
CONNECT TO DOOR
PORTAL
FLANGE W/CONNECTORS
BOLTED
MOVING-SUN SUPPORT
GANTRY ARCHES. FRAMED
FOR 50 TON SIMULATOR
LOAD. ALUMINUM W/TITANIUM
SPECIALS
MOVING-SUN UNIT
20 FEET DIA. CENTER UNIT
WING BANKS OF
THERMAL LAMPS
REFLECTED TYPICAL OPNG'S
TO DIFFUSION PUMPS IN
OPPOSITE WALL-TOTAL
44 PUMPS
DOUBLE MANLOCK IN
NORTH WALL
TEST
UNIT
72'-0"
CRYOPANELS
LN2 THERMAL SHROUD PANELS
He CRYOPUMPING PANELS
LN2 SHIELD PANELS
SECTIONALIZED RING CONNECTORS
LN2 CRYOPANELS
NEW CHAMBER
ENTRANCE
DOOR
LOCK DOOR
32'-0" DIA.
DIFFUSION PUMP OPENINGS
SIX (6) REQUIRED
FLOOR STRUCTURE W/LN2
CRYOPANELS
WEST
TEST
ENCLOSURE
DOOR
WEST
CHAMBER
DOOR
GANTRY FRAME
DRIVE UNITS
TWO UNITS
OUTLET
GRILLES
TRAVELING DOOR SUPPORTS
SPRING OR HYDRAULIC LOADED
CIRCULAR CRANE
RAILS AND SUPPORTING
GIRDERS AND COLUMNS
CHAMBER FLOOR
CENTER
ANCHORING
PIER
TYPICAL
CHAMBER
COLUMN
PLENUM
REPRESSURIZATION
DUCT
DOOR HINGE &
RING-CONNECTORS
SUPPORT
CONNECT TO DOOR
PORTAL
MOVABLE LOCK
SUPPORT PLATFORM
MOUNTED ON RAIL
TRUCKS
DOOR HINGE LOAD
CARRIED TO PLATFORM
GRAPHIC SCALE
0 4 8 16 24
1/8" = 1'-0"
TENSION
PILES
EQUIPMENT LOCK
37'-0" DIA. x 61'-0" LONG
EAST WEST LONGITUDINAL SECTION ℄ TEST CHAMBER
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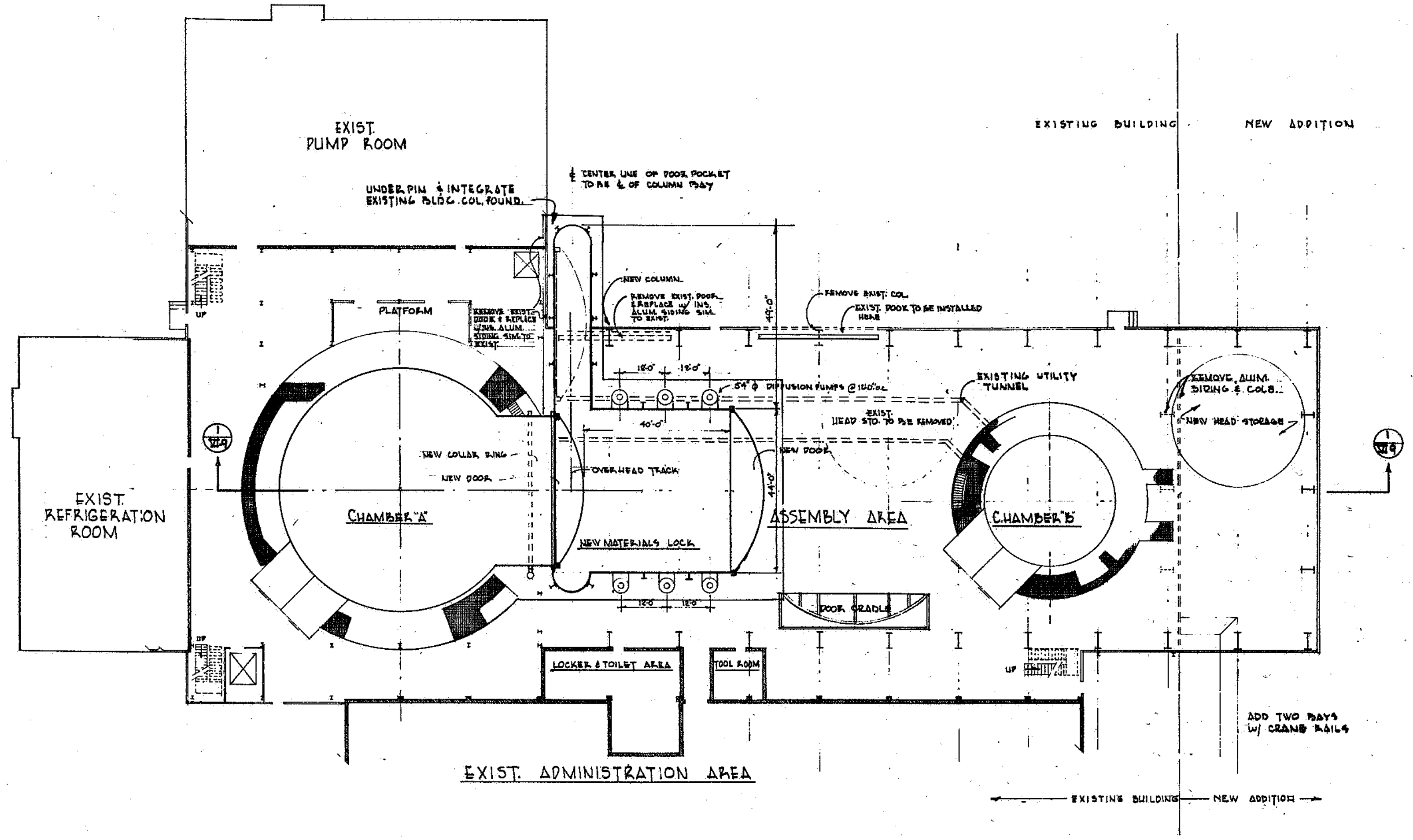
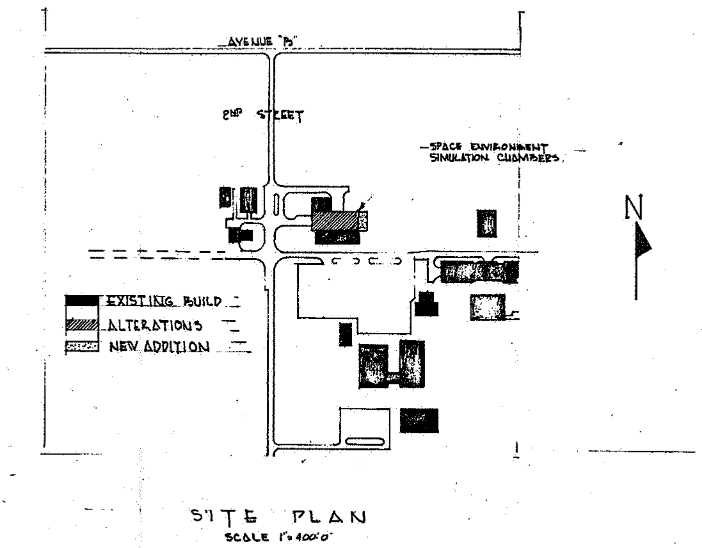
SPACE PROPULSION FACILITY
PLUM BROOK STATION
MODIFICATIONS
CHAMBER ELEVATION SECTION
MOVING SUN DETAILS
15 DEC. 1964 DRAWING NO VI-7





SITE PLAN
SCALE 1" = 400'-0"

OUTLINE SPECIFICATIONS
EXISTING CONDITIONS

ADMINISTRATION AREA

FOUNDATIONS	REINFORCED CONCRETE ISOLATED FOOTINGS WITH DRILLED-IN AND UNDER-REAMED R.C. PILING AND/OR PRECAST CONCRETE PILING.
FRAMING SUPERSTRUCTURE	STRUCTURAL STEEL WITH SPRAYED ON FIREPROOF COATING.
GROUND FLOOR	CONCRETE SLAB ON COMPACTED ROCK FILL.
2ND FLOOR	CONCRETE SLAB ON METAL DECKING ON STRUCTURAL STEEL FRAMING.
ROOF	BUILT-UP ROOFING ON LIGHTWEIGHT CONCRETE ON METAL DECKING ON STRUCTURAL STEEL FRAMING.
EXTERIOR WALLS	CONTINUOUS ALUMINUM WINDOW PANELS WITH PRECAST CONCRETE FASCIA PANELS WITH INSULATED ALUMINUM SANDWICH PANELS.
SUSPENDED CEILINGS	ACOUSTICAL TILE OR METAL LATH AND PLASTER.

CHAMBER AREA

FOUNDATIONS	REINFORCED CONCRETE ISOLATED FOOTINGS WITH DRILLED-IN AND UNDER-REAMED CAST-IN-PLACE R.C. PILING AND/OR PRECAST R.C. PILING.
CHAMBER FOUNDATION WELLS	REINFORCED CONCRETE, CONTINUOUS MAT FOUNDATION WITH CONTINUOUS WATERPROOFING MEMBRANE WITH PRECAST CONCRETE PILING.
GROUND FLOOR	CONCRETE SLAB ON COMPACTED ROCK FILL.
ROOF	LIGHTWEIGHT CONCRETE ON METAL DECKING ON STRUCTURAL STEEL FRAMING.
EXTERIOR WALLS	INSULATED ALUMINUM SANDWICH PANELS.
TRAVELING BRIDGE CRANE	50/10 TON CAPACITY.
EXTERIOR MATERIAL DOOR	ROLL-UP METAL.

CHAMBER "A"

CHAMBER	RIGHT CIRCULAR CYLINDER WITH SPHERICAL SEGMENT TOP HEAD AND ELLIPSOIDAL BOTTOM HEAD. 65'-0" I.D. 117' TOTAL CHAMBER HEIGHT. 79'-6" SIDESHEET. TOP HEAD 82.00' ELEVATION. LUNAR PLANE AT EL. 0.00'. CHAMBER SUPPORTED ON 15 COLUMNS.
MANLOCKS	ONE-SINGLE MANLOCK, ONE-FUTURE SINGLE MANLOCK. ONE-DOUBLE MANLOCK.
VEHICLE ACCESS DOOR	40'-0" I.D. CIRCULAR. BOTTOM EL. 1.50'.
VACUUM SYSTEM	MECHANICAL ROUGHING AND BACK-UP PUMPS. DIFFUSION PUMPS, HELIUM CRYOPANEL PUMPING. PRESSURE-CLEAN 1 x 10-8 TORR. PRESSURE RATED LOAD TESTING 1 x 10-5 TORR.
THERMAL HEAT SINK	LIQUID NITROGEN COOLED PANELS WALLS AND LUNAR PLANE.
SOLAR SIMULATION	FIXED TOP SUN AND SIDE SUN. AUTOMATIC-FEED CARBON-ARC LAMP MODULES. 32 KW RATED INPUT EACH MODULE. 43 MODULES (314 SQ. FT. IRRADIATED AREA ON LUNAR PLANE) TOTAL FUTURE TOP SUN; 19 MODULES PRESENT PLUS 24 FUTURE. SIDE SUN IRRADIATED AREA OF CHAMBER, 13 FOOT WIDTH x 40 FOOT HEIGHT PRESENT, TOTAL FUTURE 20 FOOT WIDTH x 65 FOOT HEIGHT.
VEHICLE HOISTING	4-25 TON CAPACITY EACH HOISTS OPERATING THROUGH TOP HEAD PORTS.
LUNAR PLANE	ROTARY LUNAR PLANE TURNTABLE WITH CRYOPANEL COOLING PANELS AND ELECTRICAL RESISTANCE TYPE HEATING.
REPRESSURIZATION AIR SYSTEM	LUNAR PLANE PERIPHERY INLET AIR GRILLES FROM REPRESSURIZATION ANNULUS AROUND BOTTOM HEAD OF CHAMBER.

MODIFICATIONS

SPACE ENVIRONMENTAL SIMULATION CHAMBERS
CHAMBER "A", MANNED SPACECRAFT CENTER, HOUSTON

1. CHAMBER "B" OPERATIONS - NO CHANGE.
2. INCREASE SIDE-SUN MODULES NUMBER TO PROVIDE FOR 20 FOOT x 20 FOOT CAPABILITY AT LOWER (SUNRISE) POSITION.
3. INCREASE TOP-SUN LAMP MODULE NUMBER TO PROVIDE FOR FULL DIAMETER TOP SUN CAPABILITY.
4. ADD NECESSARY ELECTRIC POWER AND LAMP MODULE CONTROL EQUIPMENT.
5. PROVIDE NEW MATERIALS LOCK, COMPLETE, WITH NEW CHAMBER DOOR COLLAR RING WITH SUPPORT, NEW CHAMBER DOOR, CHAMBER DOOR POCKET, DOOR SLIDING AND LIFTING MECHANISM, MATERIALS LOCK WITH FOUNDATIONS, NITROGEN COOLED THERMAL SHROUD CRYOPANELS, SIX (6) DIFFUSION PUMP STATIONS COMPLETE WITH COLD-TRAPS AND VACUUM CLOSURE VALVES, NEW LOCK DOOR AND DOOR CRADLE. MATERIALS LOCK TO BE COMPOSED OF STAINLESS STEEL PLATES AND CARBON STEEL FRAMING EXTERIOR TO LOCK. CRYOPANELS SHALL BE ALUMINUM.
6. RELOCATE EXISTING ASSEMBLY AREA MATERIAL ENTRANCE DOOR.
7. EXTEND CHAMBER AREA BUILDING AND CRANE RAIL TWO BAYS.
8. RELOCATE EXISTING CHAMBER "B" HEAD STORAGE PLATFORM TO NEW BUILDING EXTENSION AREA.
9. PROVIDE ALL NECESSARY ELECTRIC POWER, CRYOGENIC SUPPLY, VACUUM PIPING, INSTRUMENTATION AND CONTROL CONNECTIONS TO MATERIALS LOCK.
10. INCREASE LIQUID NITROGEN CAPACITY FOR FULL CHAMBER "A" AND MATERIALS LOCK THERMAL SHROUD LOAD. ADD LUNAR PLANE THERMAL CONTROL.
11. ADD VEHICLE EXERCISE SYSTEM TO LUNAR PLANE.

GRAPHIC SCALE
1/16" = 1'-0": 0 4 8 12 16 32 48
1" = 400': 0 100 200 300 400 800 1200

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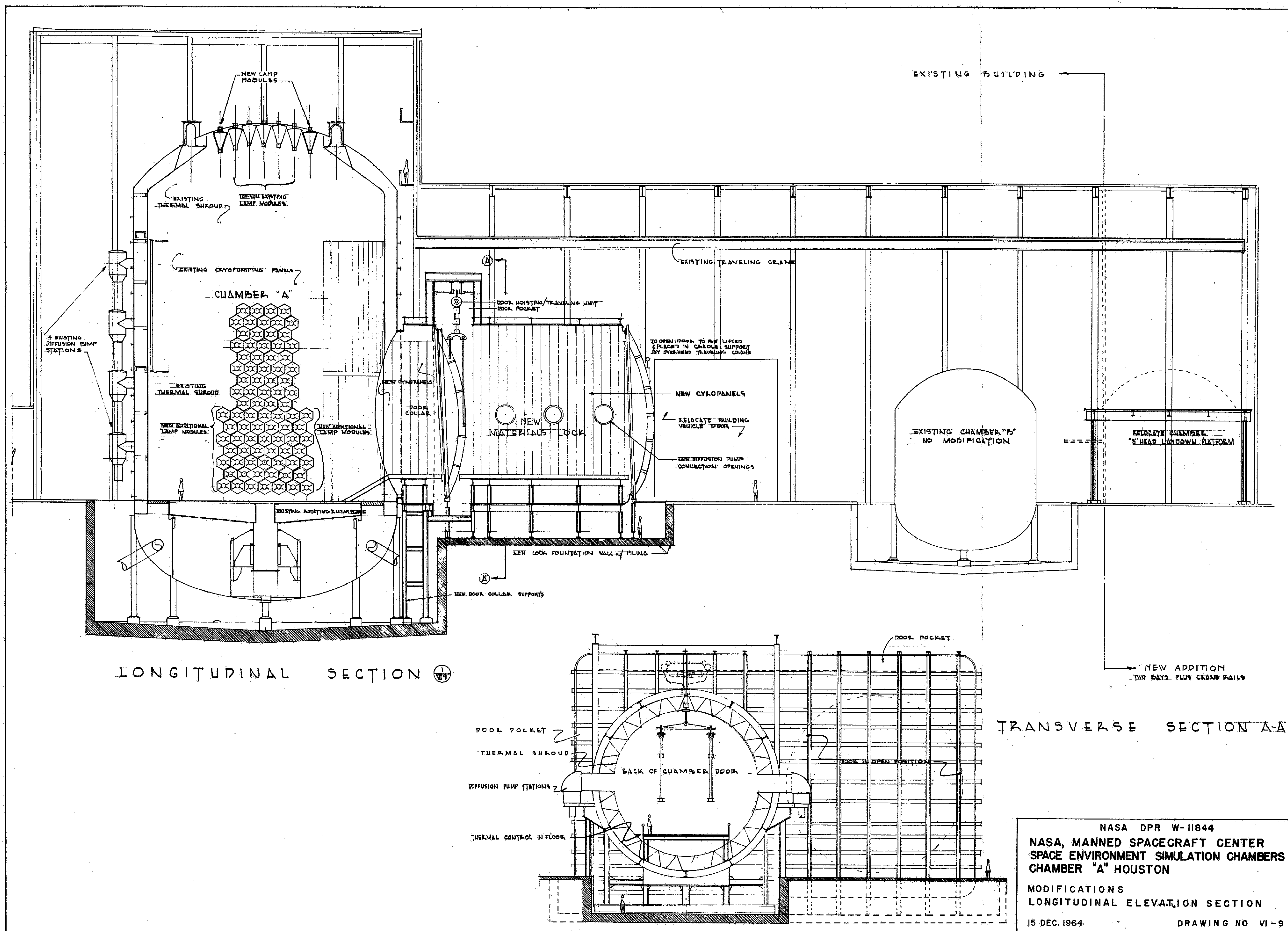
SPACE ENVIRONMENT SIMULATION CHAMBERS
CHAMBER "A" HOUSTON
MODIFICATIONS
PLAN-OUTLINE SPECIFICATIONS
15 DEC. 1964 DRAWING NO VI-8



EXISTING BUILDING
NEW LAMP MODULES
EXISTING THERMAL SHROUD
TO BE EXISTING LAMP MODULES
EXISTING CRYOPUMPING PANELS
CHAMBER "A"
74 EXISTING DIFFUSION PUMP STATIONS
EXISTING THERMAL SHROUD
NEW ADDITIONAL LAMP MODULES
NEW ADDITIONAL LAMP MODULES
EXISTING TRAVELING CRANE
DOOR HOISTING/TRAVELING UNIT
DOOR POCKET
NEW CYROPANELS
DOOR COLLAR
NEW MATERIALS LOCK
TO OPEN: DOOR TO BE LIFTED & PLACED IN CRADLE SUPPORT BY OVERHEAD TRAVELING CRANE
NEW CYROPANELS
RELOCATE BUILDING VEHICLE DOOR
NEW DIFFUSION PUMP CONNECTION OPENINGS
EXISTING CHAMBER "B" NO MODIFICATION
RELOCATE CHAMBER "B" HEAD LAYDOWN PLATFORM
NEW LOCK FOUNDATION WALL w/ PILING
NEW DOOR COLLAR SUPPORTS
LONGITUDINAL SECTION
DOOR POCKET
NEW ADDITION
TWO BAYS PLUS CRANE RAILS
TRANSVERSE SECTION A-A
DOOR POCKET
THERMAL SHROUD
BACK OF CHAMBER DOOR
DOOR IN OPEN POSITION
DIFFUSION PUMP STATIONS
THERMAL CONTROL IN FLOOR
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SPACE ENVIRONMENT SIMULATION CHAMBERS
CHAMBER "A" HOUSTON
MODIFICATIONS
LONGITUDINAL ELEVATION SECTION
15 DEC. 1964
DRAWING NO VI-9

APPENDIX A: LETTER OF AUTHORITY AND WORK STATEMENT

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington 25, D. C.

M-C MCL 1400 Jun 26 1964

Brigadier General E. E. Wilhoyt, Jr.
Assistant to the Chief of Engineers
for the National Aeronautics and
Space Administration Support
Office of the Corps of Engineers
Washington, D. C.

Dear General Wilhoyt:

Your letter of June 16, 1964, forwarded a proposed work statement drawn up in conjunction with Mr. J. Wilhelm of my office. It outlines a study of our requirements for a space environment simulator to carry out the testing of the Apollo Logistics Support System. The letter indicates your willingness to undertake this effort for us at a cost of approximately $30,000 and in a time period which is agreeable to us as indicated. However, we have added one additional sentence to item number three of the tabulation of requirements in the proposed work statement. It identifies our need for the requirements and costing to be broken down into two segments, i.e., requirements to do major systems testing and additional requirements to be capable of combined systems testing. This change has been discussed with Mr. Wendell of your office and has his concurrence. The modified work statement is enclosed.

We desire that you undertake this study for us and are anxious that the effort begin as soon as possible. However, please understand that this investigation does not necessarily imply follow-on design effort in this area.

We trust that this letter will suffice to commit us to the arrangement as outlined in your letter. The documentation to transfer the funds will be initiated immediately and should be in your hands in a short while.

Sincerely,

/s/

George E. Mueller
Associate Administrator
for Manned Space Flight

Enclosure

COPY

WORK STATEMENT FOR ANALYSIS OF APOLLO LOGISTIC SUPPORT SYSTEM TEST FACILITY REQUIREMENTS

In recent weeks the office of Manned Space Flight has established a Test Philosophy and Outline Test Program for the Apollo Logistic Support System Payloads. They are summarized in a document bearing that title which is dated May 1964. There now is a requirement to analyze the various chambers that exist around the country to determine whether or not any have the capability to fulfill these requirements as they are presently designed, and what modifications would be necessary to make any particular one capable of handling the test program. Requirements for which analysis is required are those described under major systems testing and combined systems testing covered in paragraphs 8 and 9 of the document. The capabilities in paragraph 8.3.1. "Vacuum Test Facilities" are to be provided in one chamber. The capabilities in paragraph 9 "Combined Systems Testing" are to be provided in one chamber with the exception of the dynamic tests in paragraph 9.2.3.

Specific services required are as follows: (1) An updated tabulation of the capabilities of the large chambers and nuclear power test facility contained in "Special Study of the Research and Development Effort Required to Provide a U. S. Lunar Construction Capability, "Volume Two, Appendices B and C. (2) An evaluation of the engineering feasibility for meeting the stated test requirements. (3) Development of concepts for accomplishing the various requirements in sufficient detail to be used in determining scope of chamber modifications and cost estimates. Scope of chamber modifications and cost estimates will be developed in two phases: (a) Requirements and costs to carry out the testing of major systems, and (b) additional requirements and costs to be able to carry out the combined systems testing. (4) Evaluation of existing chambers to determine which, if any, could handle the test requirements, modifications necessary to provide the required capability, the feasibility of making such modifications, the estimated costs of modification and the approximate time for construction of the modifications.

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Based on a starting date for the analysis of July 1, 1964, a final report will be submitted on December 15, 1964. An interim report will be submitted on October 1, 1964, and will contain a tabulation of chamber capabilities, preliminary engineering feasibility analysis and preliminary development of concepts for accomplishing the various requirements.

APPENDIX B: TEST PHILOSOPHY AND OUTLINE TEST PROGRAM FOR APOLLO LOGISTIC SUPPORT SYSTEM PAYLOADS

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TEST PHILOSOPHY

AND

OUTLINE TEST PROGRAM

FOR

APOLLO LOGISTIC SUPPORT SYSTEM PAYLOADS

May 1964

ADVANCED MANNED LUNAR MISSIONS

OFFICE OF MANNED SPACE FLIGHT

ABBREVIATIONS

ALSS	Apollo Logistic Support System
LEM	Lunar Excursion Module
LEM Truck	LEM descent stage modified to carry cargo
LRV	Lunar Roving Vehicle
LFV	Lunar Flying Vehicle

INDEX

1. INTRODUCTION

1.1 This document presents a test philosophy and outlines in general terms a test program for ALSS payloads. The purpose of the document is to aid in the definition of the scope of work, equipment and facilities which the ALSS payload test program will require.

1.2 It is emphasized that the material contained herein is preliminary in nature and general in scope. Since the ALSS configuration is not yet fixed, the test program cannot be defined in detail. However, quantitative information is used where possible.

1.3 ALSS payloads of interest are the following:

1.3.1 Of prime interest: A LRV capable of sheltering and transporting 2 astronauts on a 14-day lunar surface exploration missions extending over several hundreds of miles. The LRV would be supplemented by appropriate support equipment, scientific instrumentation and expendables. The payload probably would also include a light-weight, two-man LFV of limited range.

1.3.2 Of secondary interest: A similar payload in which the LRV is replaced by a stationary shelter/laboratory and a small LRV of limited range.

1.4 The test program does not consider the development testing of the LEM Truck per se, it being assumed that such testing will closely parallel that of the Apollo LEM and that suitable test facilities will be available.

1.5 The program outlined herein treats only development testing and does not consider acceptance testing or checkout of operational payloads.

2. TEST PHILOSOPHY

2.1 The environmental test program will follow the philosophy of thoroughly testing materials, parts, components, subsystems, major systems and combined systems, in that order, whenever practicable.

2.2 These categories of testing are defined briefly as follows:

2.2.1 Materials Testing

Qualification of materials which will be considered for use in the manufacture of payloads.

2.2.2 Parts Testing

Qualification of parts or assemblies of parts.

2.2.3 Components Testing

Testing of small functional assemblies such as instruments, black boxes, etc.

2.2.4 Subsystem Testing

Testing of grouped components which operate as a system -- i.e., power system, life support equipment, air lock, suspension system, etc.

2.2.5 Major System Testing

Testing of major pieces of equipment such as the LRV, shelter/lab etc. These tests will include manned operation.

2.2.6 Combined Systems Testing

Testing of complete payloads together with the LEM Truck. These tests will also include manned operation.

2.3 It is recognized that due to practical and economic considerations the degree to which actual operational environments can be simulated in the test program will vary with the phase of testing. Extreme high fidelity is achievable and essential in the testing of materials, parts, components and subsystems. Less accurate simulation is acceptable for testing major systems and combined systems.

2.4 In the interest of economy, every effort will be made to exploit model testing. However, model testing cannot be assumed to be a substitute for full scale testing, nor does it eliminate the need for full scale test facilities. Rather, it is a technique which can be used to lessen the load on major facilities and make more facility time available for critical, full scale tests.

2.5 Wherever practicable in the test program, combinations of conditions to which the payloads will be exposed should be imposed simultaneously upon test articles. Where simultaneous exposure is not practicable, sequential exposure is permissible.

2.6 Astronaut participation will be included in the testing of major and combined systems in order to provide both system development data and valuable training.

2.7 Extensive terrestrial field tests will also be a part of major systems and combined systems testing. This will provide not only design information but training and data for mission planning.

2.8 Existing environmental simulation facilities will be utilized to the maximum practicable extent in the ALSS test program, and test plans may be significantly influenced by the characteristics and limitations of such facilities. However, compromises will not be made which substantially reduce the prospects of mission or project success.

2.9 NASA documents of the series NPC-200 entitled "Quality Program Provisions for Space System Contractors" shall be used where applicable

3. ASSUMPTIONS

3.1 For the purpose of assisting in the preliminary definition of facilities to be used in major systems testing and combined systems testing, it is estimated that major ALSS equipment items will have the following approximate dimensions and weights:

3.1.1 LEM Truck without payload but with legs deployed: 33 ft. diameter and 12 ft. high; weight, 21,800 lbs. fueled and 5,600 lbs. dry.

3.1.2 ALSS payloads as packaged on the LEM Truck: the frustrum of a right circular cone 10 ft. high with an 18 ft. diameter base and 15 ft. diameter top; weight, 8,000 lbs.

3.1.3 ALSS shelter/laboratory: same as 3.2.

3.1.4 ALSS LRV when deployed: maximum dimensions of 16 ft. wide, 13 ft. high, and 42 ft. long; weight, 6,500 lbs.

3.2 For the purpose of defining the test program it is assumed that the ALSS payloads will be subjected to a six month period of storage on the lunar surface followed by a 14-day period of operation. (This does not necessarily establish a requirement for a six month vacuum and thermal test).

4. ALSS ENVIRONMENT

4.1 The ALSS payloads will be designed and tested to perform their intended functions in the environment specified in the NASA document, "Natural Environment and Physical Standards for Project Apollo", (M-D E 8020.008A).

4.2 The ALSS payloads will also be designed and tested to withstand the accelerations, vibrations, and shocks imposed by the Saturn-Apollo vehicle systems.

5. PARTS AND MATERIALS TESTING

5.1 General

5.1.1 Prior to selection for ALSS applications, materials and parts will be qualified to establish operational and functional integrity, and to verify endurance under appropriate environmental conditions.

5.1.2 Every effort will be made to utilize materials and parts already qualified to appropriate specifications in the Apollo and other programs. New qualification testing will be initiated only when it has been established that suitable qualified parts are unavailable. The services of Inter-Service Data Exchange Program (IDEP) and Electronic Component Reliability Center (ECRC) will be utilized in making these determinations.

5.1.3 An approved materials and parts list will be established during preliminary design and will be maintained throughout the development program.

5.1.4 General guidance and policy on materials and parts testing is outlined in NASA document, "Reliability Program Provisions for Space System Contractors" (NPC 250-1) dated July 1963), paragraph 3.9.

6. COMPONENT TESTING

6.1 General

Prior to incorporation into a subsystem, components will be thoroughly tested to verify operational and functional integrity. To the extent technically feasible, components will be tested under conditions which accurately reproduce the operational environment.

6.2 Examples

Typical components to be tested are: valves, couplings, regulators, leveling devices, motors, transmissions and LRV suspension devices.

6.3 Criteria for Vacuum Test Facilities

For components which are exposed to the space and lunar environment, test facilities will be required which have the following capabilities:

6.3.1 Vacuums greater than 10^{-10} torr.

6.3.2 Solar simulation closely matching the Naval Research Laboratory spectrum.

6.3.3 Thermal simulation with a temperature range of $+250^{o}F$ to $-250^{o}F$, including accurate reproduction of applicable thermal radiation and conduction effects.

7. SUBSYSTEM TESTING

7.1 General

7.1.1 Subsystems will be thoroughly tested to verify operational and functional integrity. To the extent technically feasible, components will be tested under conditions which accurately reproduce the operational environment.

7.1.2 Particular importance is attached to subsystem testing, since technical and economic considerations dictate that subsystems will be the largest ALSS elements tested under conditions closely resembling the operating environment.

7.2 Examples

The sizes and types of subsystems to be tested and the kinds of tests involved will vary widely. Representative examples are listed below:

7.2.1 Air Locks

Air locks will be tested to evaluate pressure cycling during ingress-egress operations to verify functioning under vacuum, temperature and pressure differential conditions. A typical air lock will measure 4 ft. in diameter and 7 ft. in height.

7.2.2 Test Panels

Structural panels approximately 2 ft. by 4 ft. will be tested to assist designers to define shelter wall structures. Curved as well as flat sections will be tested. The following types of panel tests will be performed:

7.2.2.1 Meteoroid Puncture

High velocity puncture tests will be conducted to establish effects of penetration and optimum design.

7.2.2.2 Insulation and Bonding

Thermal tests will be performed to check both thermal gradients and bonding integrity.

7.2.2.3 Compression Tension and Shear

Panels will be subjected to critical structural loads including thermal effects.

7.2.2.4 Thermal Cycling

Thermal cycling tests will be conducted to evaluate displacements, distortions and unit strains.

7.2.3 Cryogenic Tanks and Associated Storage

Cryogenic tanks will be tested in the following manners:

7.2.3.1 Long Storage Evaluation

Cylindrical and spherical tanks up to 5 ft in diameter will be tested to evaluate their long-term storage capabilities under simulated lunar conditions.

7.2.3.2 Sloshing Tests

Tanks containing propellants or suitable substitutes will be subjected to the dynamic environment occurring during flight to determine sloshing frequencies and stability requirements.

7.2.3.3 Pressure and Thermal Test

Tanks will be tested under appropriate temperature and pressure environments to test structural integrity, freedom from leaks and the effectiveness of insulation.

7.2.4 Thermal Control System Tests

Tests will be conducted to evaluate radiator configurations and passive thermal control surfaces.

7.2.5 Antenna Tests

Various techniques for folding and deploying antennas will be tested. This will include effects of the lunar thermal cycle. Dishes up to 5 ft. in diameter will be considered.

7.2.6 Power Source Tests

The fuel cell power sources for the LRV and shelter/laboratory should be exhaustively tested in a vacuum facility. Such tests may present problems because of the presence of cryogenic hydrogen and oxygen in a confined space.

7.2.7 LRV Locomotion Assembly Tests

LRV locomotion assemblies (includes wheel, electric drive motor, transmission, braking, steering and thermal control equipment) will be tested to evaluate suspension and locomotion characteristics. Tests under simulated lunar surface conditions will evaluate performance on a variety of lunar soil simulants. Tests will include braking, steering, dynamic response, wear, and functioning of both active and passive systems for removing heat from the motor and transmission. Wheels up to 6 ft. in diameter will be tested.

7.3 Criteria for Test Equipment and Facilities

7.3.1 Vacuum Test Facilities

For subsystems which are exposed to the space and lunar environment, test chambers will be required which have the following capabilities:

7.3.1.1 Vacuums greater than 10^{-10} torr.

7.3.1.2 Solar simulation approximating the Naval Research Laboratory spectrum to cover areas up to about 12 ft in diameter.

7.3.1.3 Thermal simulation with a temperature range of +250°F to -250°F, including accurate reproduction of thermal radiation and conduction effects and provision for varying temperatures at the rates occurring on the moon.

7.3.1.4 For the testing of wheel systems, provisions to handle lunar soil simulants, preferably to a depth of several feet.

7.3.1.5 Sufficient space to permit testing subsystems as large as 8 ft. by 8 ft. by 12 ft., including a treadmill where required.

7.3.1.6 An air lock of sufficient size to permit inserting and removing test articles with minimum disturbance to the test environment.

7.3.2 Other Test Equipment

Other major items of equipment for subsystem testing will include:

7.3.2.1 Structural test equipment.

7.3.2.2 Equipment for conducting vibration and shock tests on subsystems weighing up to 1,000 lbs.

7.3.2.3 Equipment for determining weights, moments of inertia and centers of gravity.

8. MAJOR SYSTEMS TESTING

8.1 General

8.1.1 Major systems will be subjected to a wide range of engineering and operational tests with the objective of providing:

8.1.1.1 Design data, in both engineering and human factors areas.

8.1.1.2 A continuing check on the progress and technical adequacy of system development through tests of a series of test articles.

8.1.1.3 Final qualification of complete systems.

8.1.1.4 Operational planning data.

8.1.1.5 Familiarization training for astronauts in operating and maintaining ALSS payloads.

8.1.2 Both manned and unmanned tests will be conducted.

8.1.3 For systems testing, lower fidelity environmental simulation will be acceptable than is required for subsystem testing.

8.2 Examples

8.2.1 Principal systems to be tested will include the LRV, the LFV and the shelter/laboratory.

8.2.2 Throughout the program full scale test articles will be subjected to:

8.2.2.1 Static tests to include bending, shear, pressure and temperature effects.

8.2.2.2 Dynamic tests to simulate conditions imposed on the payload between earth launch and lunar landing. These will include vibration, shock, liquid sloshing, etc.

8.2.2.3 Dynamic tests to assess performance of the LRV on the lunar surface.

8.2.2.4 Leak rate tests performed at high pressure and extreme temperature.

8.2.2.5 Thermal constants tests performed in simulated lunar environment.

8.2.2.6 Tests to establish weight, moments of inertia and center of gravity.

8.2.2.7 Terrestrial field exercises simulating full length lunar surface missions.

8.2.3 Near the end of the test program prototypes of the major systems will be subjected to final qualification tests. These will include vibration, shock, stability, thermal and pressure tests. Final mass data will be determined, and, if practicable, prototypes will be exposed to the simulated lunar environment for long periods (in excess of 2 weeks) to see if there are time-dependent effects.

8.3 Criteria for Test Equipment and Facilities

8.3.1 Vacuum Test Facilities

For systems tests, environmental simulation facilities will be required which have the following capabilities:

8.3.1.1 Vacuum of 10^{-8} torr with chamber empty and 10^{-5} torr during testing.

8.3.1.2 Solar simulation approximating the Naval Research Laboratory spectrum, and of sufficient size to irradiate the largest module of the system (irradiated field about 20 ft. in diameter). A means of varying the position of the system to simulate the movement of the sun is highly desirable.

8.3.1.3 Provisions for supplementing the solar simulation with an infrared lamp system emitting 140 watts per ft.^{2} and of sufficient size to permit irradiation of a complete LRV (length of field about 45 ft., width about 20 ft.)

8.3.1.4 A pumping system capable of operating continuously for periods of at least 2 weeks. The system should be able to handle payload outgassing at a rate of 12 lb. per day of oxygen at 5 psia, and to accommodate 100 operations of a 2-man air lock during each 2 week period.

8.3.1.5 In addition to the requirements imposed by 8.3.1.4, the pumping system may have to handle the outgassing of soil simulants. Needs and quantities are not firmly established.

8.3.1.6 Earth shine simulation including, if practicable, provision for simulating the relative motion of the earth and moon.

8.3.1.7 A temperature range from +250°F to -250°F with a rate of change equivalent to that occurring on the lunar surface. Also, simulation of surface thermal characteristics.

8.3.1.8 A radiation heat sink consisting of absorbing walls cooled to 100°K or less, and capable of absorbing a 10 KW heat load from a test article.

8.3.1.9 A test chamber of sufficient size to accommodate the largest payload system (the LRV--see 3.1.4).

8.3.1.10 An air lock of sufficient size to permit insertions of the largest payload system (see 3.1).

8.3.1.11 Man-rated for several men, including appropriate personnel air locks.

8.3.1.12 A treadmill to permit exercising the LRV.

8.3.1.13 A clear distance of 5 ft. between articles being tested and the chamber wall.

8.3.2 <u>Other Test Equipment and Facilities</u>

Other major items of equipment and facilities for systems testing will include:

8.3.2.1 A one sixth gravity simulator for testing the LRV.

8.3.2.2 A terrestrial proving ground in the southwestern U. S.

8.3.2.3 Equipment for conducting vibration and shock tests on complete systems.

8.3.2.4 Equipment for determining weights, moments of inertia and centers of gravity.

9. COMBINED SYSTEMS TESTING

9.1 General

In combined systems testing, full scale payload systems will be tested with astronauts and the LEM Truck to:

9.1.1 Demonstrate the functioning of payloads when integrated with lander.

9.1.2 Test the functioning of the LEM Truck-payload-astronaut combination in the performance of the critical operations to be performed at the point of landing.

9.2 Examples

Combined systems testing will include:

9.2.1 Long exposure of the loaded LEM Truck to a simulated lunar environment to establish the thermal characteristics of the combination, followed by

9.2.2 Manned and unmanned unloading and startup tests.

9.2.3 Dynamic tests of the loaded LEM Truck including acceleration, vibration and shock at appropriate temperatures.

9.3 Criteria for Test Equipment and Facilities

Combined systems testing will require much the same types of facilities required for systems testing. However, there are significant differences in the size of vacuum chamber required. Notably, the chamber for combined systems testing must provide:

9.3.1 An air lock or other opening such as a top hatch of sufficient size to permit entry of a loaded LEM Truck (see 3.1).

9.3.2 Sufficient space within the chamber to unload the LRV and other payloads from the LEM Truck (see 3.1).

EQUIPMENT DIMENSION CHANGES & AMPLIFICATION OF REQUIREMENTS

The following represents changes in equipment dimensions or amplification of the requirements contained in the "Test Philosophy and Outline Test Program for the Apollo Logistic Support System Payloads" dated May 1964.

The treadmill (para 8.3.1.12) should be considered for articulated motion; independent wheel suspension; multi-component testing; individual wheel drive by a vehicle possessing 4 to 6 wheels; vehicle drive by the treadmill; vehicle weight of 6,500 lbs; and no simulation of lunar gravity within the chamber.

The largest payload system (LRV - para 3.1.4 and 8.3.1.9) will be 46' long x 17' wide x 14' high with a power requirement of 5-9 KW. A representative LRV is shown in Figures B-1, B-2 and B-3. A small LRV is shown in Figure B-5.

The Lunar Flying Vehicle (para 1.3.1 and 8.2.1) will be tested in a chamber under static and thermal conditions. A representative LFV is shown in Figure B-4.

The shelter/laboratory dimensions and weight (para 3.1.3) are the same as those stated in paragraph 3.1.2. The shelter is to be tested with the LEM Truck.

The infrared lamp system (para 8.3.1.3) is to supplement the solar simulation by providing infrared only for the area outside the 20' diameter of solar simulation. High quality collimation is not intended for the infrared system.

Due to the increase in length of the LRV (para 3.1.4 and 8.3.1.9), increase the length of field of the infrared lamp system to 49 feet.

The characteristics of the solar simulation systems for the Manned Spacecraft Center chambers are satisfactory as criteria for collimation, intensity, uniformity, etc. Consideration of types of system need not be limited to carbon arc. (para 8.3.1.2)

The soil simulants (para 8.3.1.5) are to be in a thin layer only. The reflective value is the most significant; it may be desirable to use other surfaces to simulate lunar surface characteristics.

The number of men to be considered for chamber occupancy is a maximum of four; normally two will be in the chamber and two in the airlock.

The outgassing load (para 8.3.1.4) represents the leakage from the Mobile Laboratory (MOLAB) payload at an internal pressure of 5 psia.

The characteristics of the repressurization system for the Manned Spacecraft Center chambers are satisfactory as criteria for this study. (para 8.3.1.11)

The maximum intensity for earthshine simulation (para 8.3.1.6) is 1.75×10^{-3} lumens/cm^2.

The clear distance of 5 ft (para 8.3.1.13) is to be maintained between articles being tested and the chamber wall or other chamber interior surface.

The size of the airlock (para 8.3.1.10) is to be based on one segment (one-third) of the LRV.

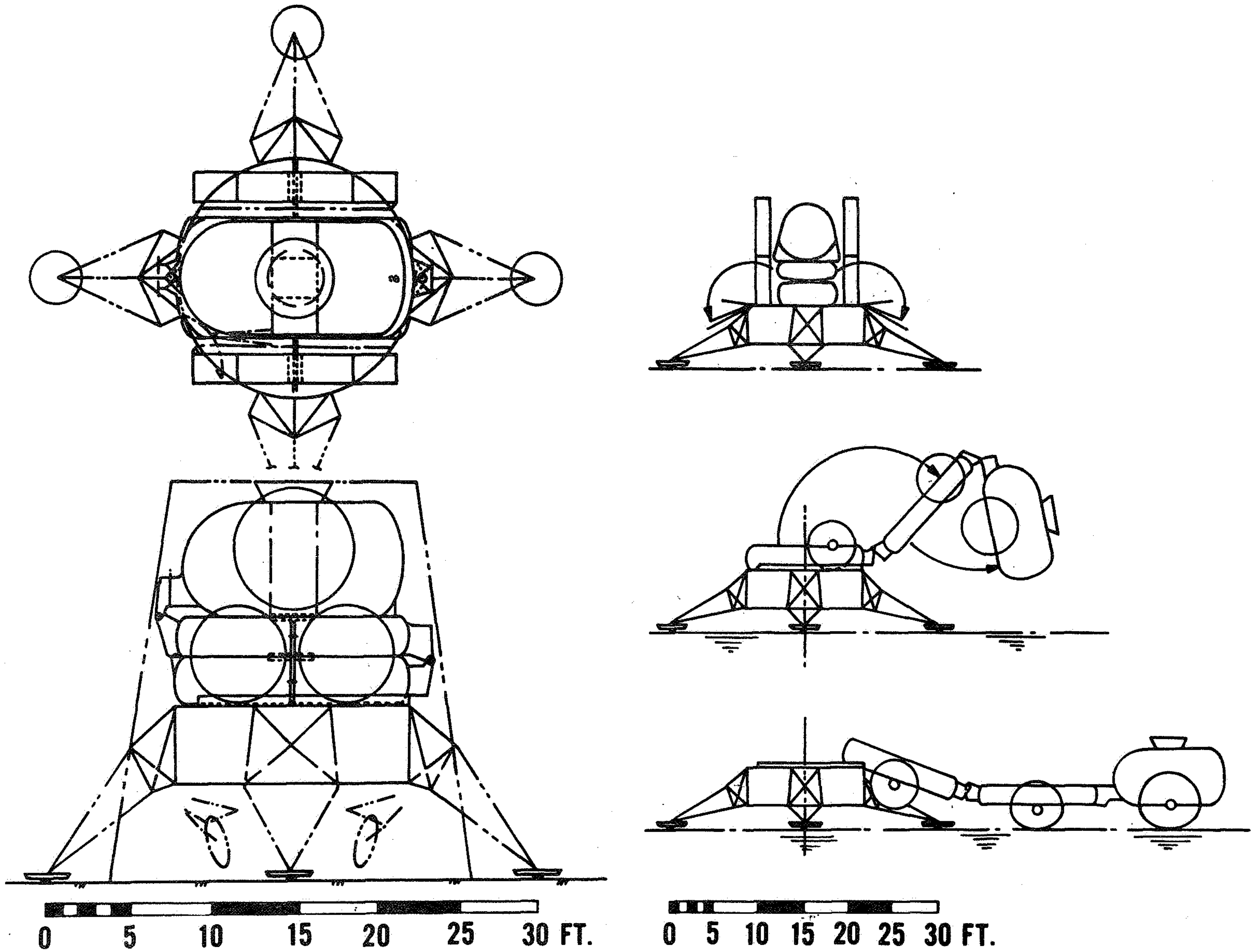


FIGURE B-1 LRV

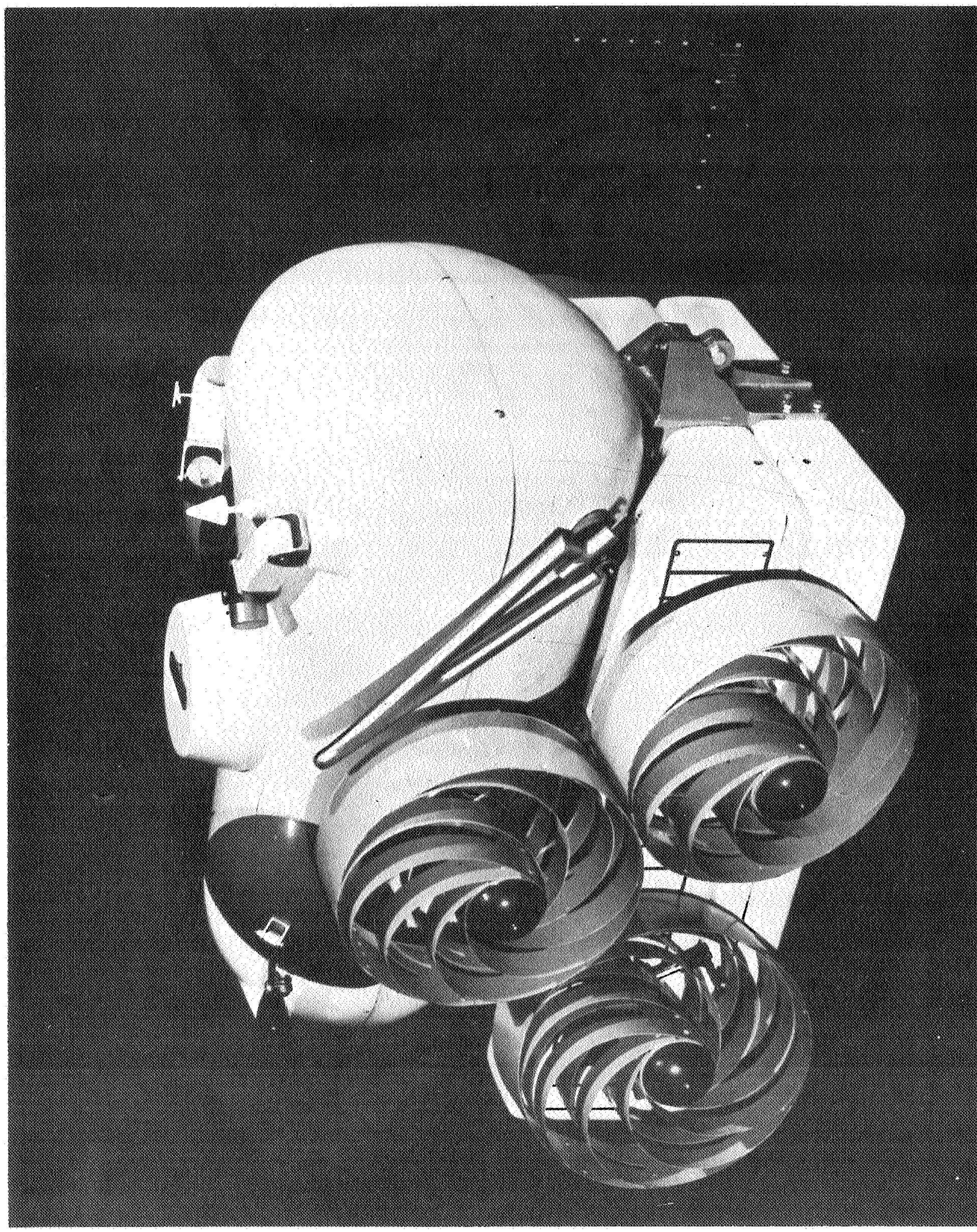


FIGURE B-2 LRV

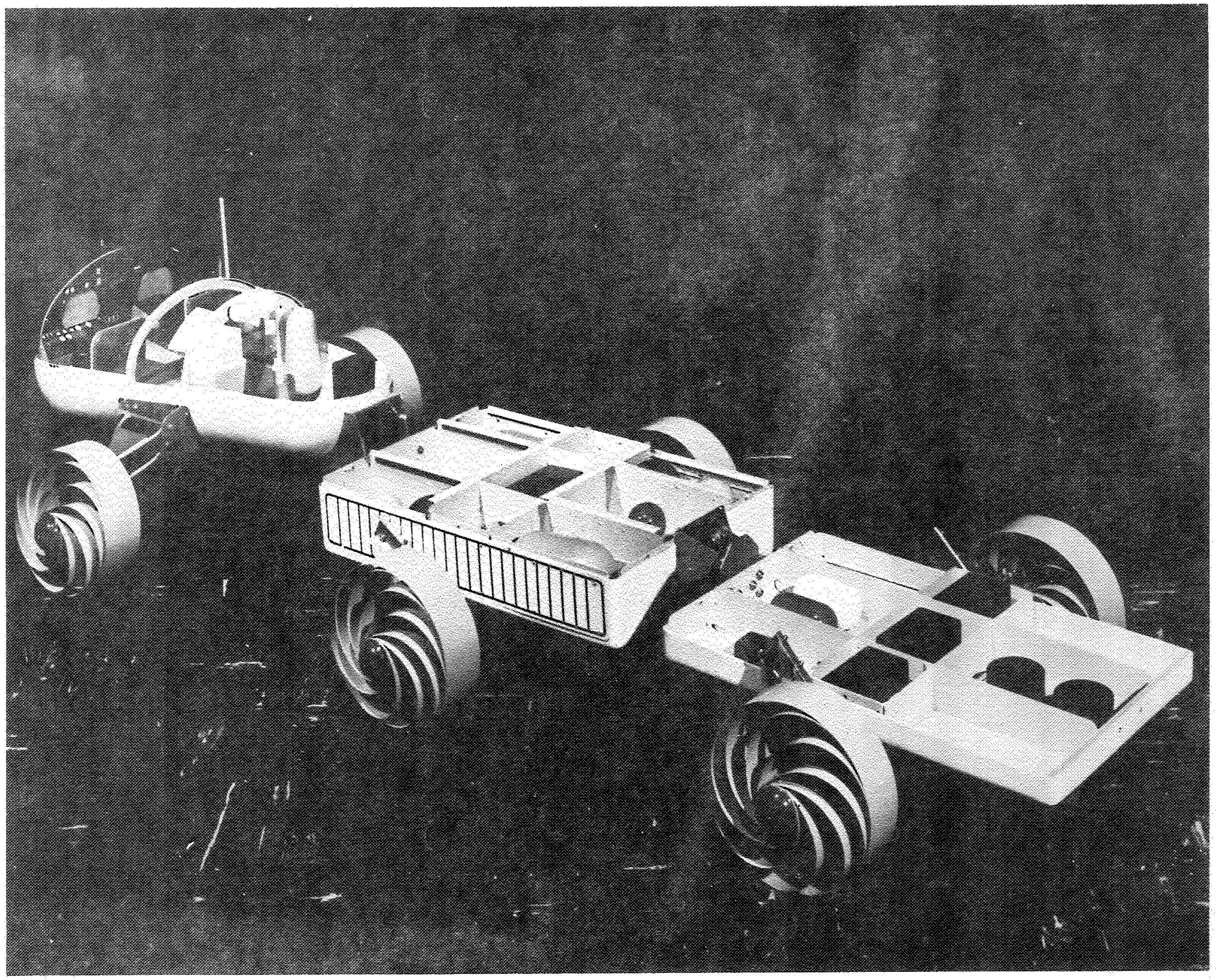


FIGURE B-3 LRV

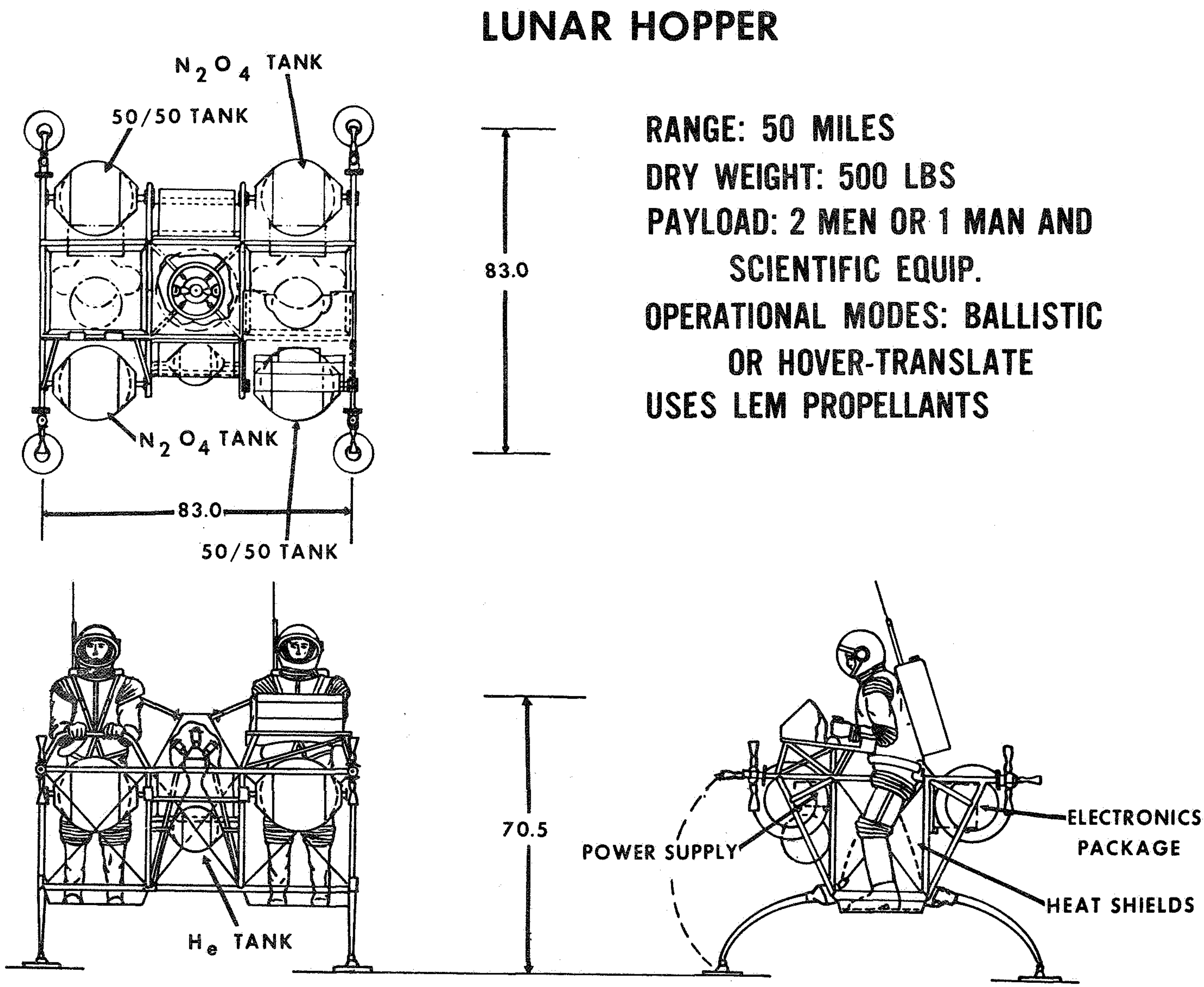


FIGURE B-4 LUNAR HOPPER

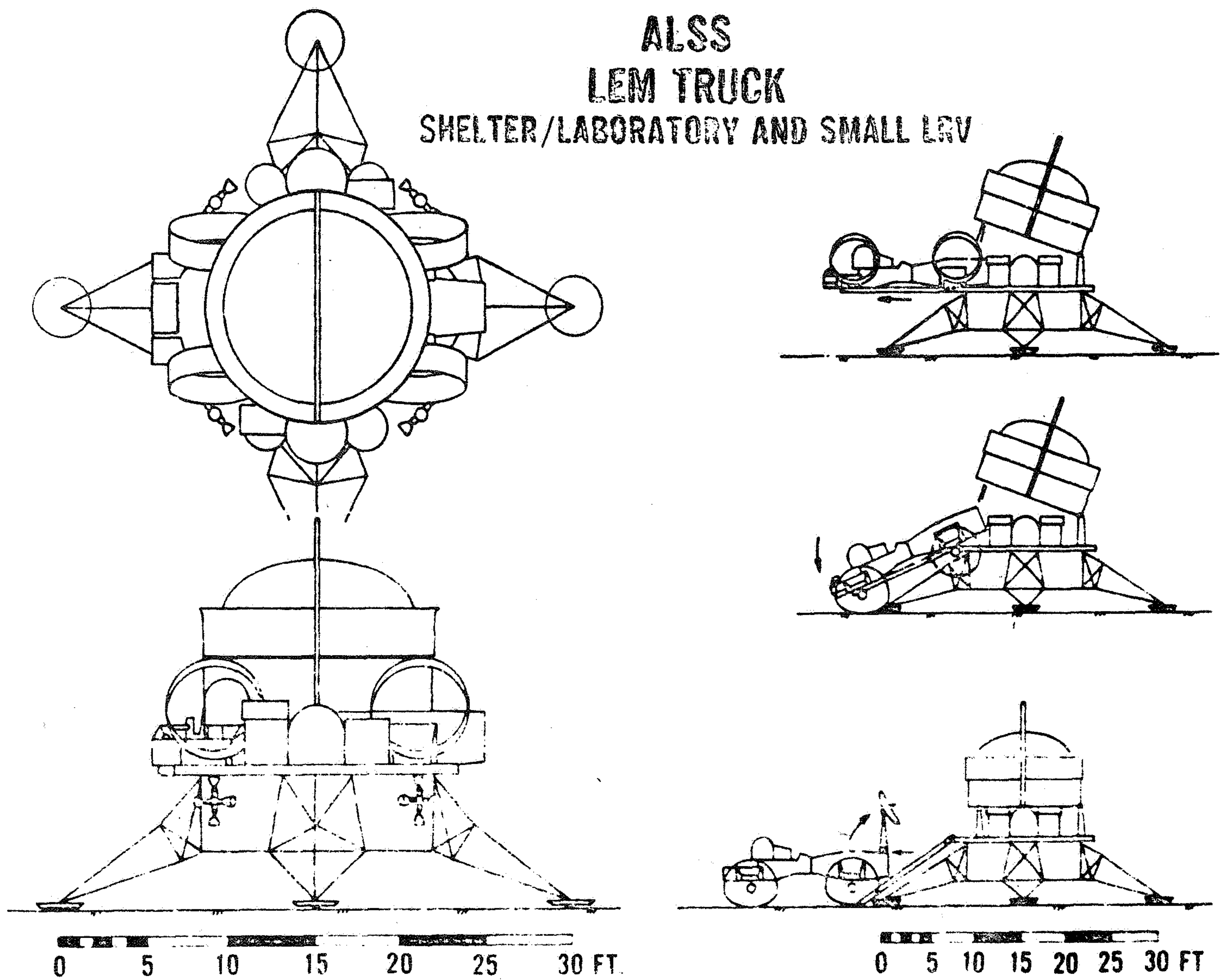


FIGURE B-5

SHELTER LABORATORY AND SMALL LRV

APPENDIX C

LARGE CHAMBERS

This appendix contains information on those existing or planned environmental test chambers which have been classified in this study as large chambers. The chambers which have been considered are described below in terms of the responsible agency, location, size and current status. The following pages contain detailed information on the capabilities of each chamber. Differences in descriptive data are due to differences in types of chambers or to differences in reporting data. In the descriptive data listings, "man-rated" refers to the capability for occupancy by men in space suits, and "materials handling equipment" refers to the availability and capability of the equipment to handle the maximum size test article. Included under "other environment capabilities" are such items as shock, vibration, heat flux, rotation of specimen, and ascent simulation.

1. NASA Manned Spacecraft Center, Houston, Texas. 65' dia x 117' 2" high (Chamber A). Under construction.

2. NASA Manned Spacecraft Center, Houston, Texas. 35' dia x 41' 8" (Chamber B). Under construction.

3. U.S. Air Force Arnold Engineering Development Center, Tullahoma, Tennessee. 42' dia x 82' high (Mark I). Under construction.

4. NASA Goddard Space Flight Center, Greenbelt, Maryland 35' dia x 60' high (Space Environment Simulator). In operation.

5. NASA Goddard Space Flight Center, Greenbelt, Maryland. 35' dia x 60'high (Dynamic Test Chamber). In operation.

6. General Electric Company, General Electric Space Center Valley Forge, Pennsylvania. Three 39' dia spheres. In operation.

7. General Electric Company, General Electric Space Center, Valley Forge, Pennsylvania. 32' dia x 54' high. In operation.

8. U.S. Air Force, not sited. 200' dia sphere (Mark IIA). Proposed; not funded.

9. NASA Lewis Research Center, Cleveland, Ohio. 30' dia x 100' long portion of altitude wind tunnel converted to space chamber. In operation.

10. NASA Marshall Space Flight Center, Huntsville, Alabama. 40' dia x 80' high. Inactive - no longer proposed.

11. NASA Langley Research Center, Hampton, Virginia. 55' dia x 55' high. In operation.

12. NASA Langley Research Center, Hampton, Virginia. 60' dia sphere. Under construction.

13. NASA Langley Research Center, Hampton, Virginia. 60' dia sphere. Proposed for FY 65 budget.

14. Douglas Aircraft Company, Douglas Space Systems Center, Huntington Beach, California. 39' dia sphere. In operation.

CHAMBER 1

Agency and Location	NASA Manned Spacecraft Center Houston, Texas
Name of facility:	Space Environment Simulation Facility, Chamber A
Purpose of facility:	Spacecraft testing and astronaut training
Size:	65' dia x 117'2" high
Work space dimensions:	45' dia x 78' high. 40' dia side opening door for loading chamber
Maximum size of test article:	25' dia (up to 40' with appendages) x 75' high; 150,000 lbs
Materials handling equipment:	Yes (Four 25 ton hoists)
Man-rated:	Yes
Personnel entry locks:	Double manlock at lunar plane level
Type of repressurization system:	1. Repressurize with oxygen and nitrogen from 0 to 6 $\pm$ 1/2 psia total pressure and oxygen partial pressure of 4 $\pm$ 1/2 psia in 30 seconds; pressure can be held at 6 psia; pressurize with air from 6 psia to atmospheric within 60 seconds. 2. Repressurize from 10^{-5} torr to 6 psia in 30 minutes. 3. Repressurize from 10^{-5} torr to 14.7 psia in 3 hours.
Minimum operating pressure:	10^{-5} torr
Gas load that can be removed at this pressure:	27.6 torr liters/sec

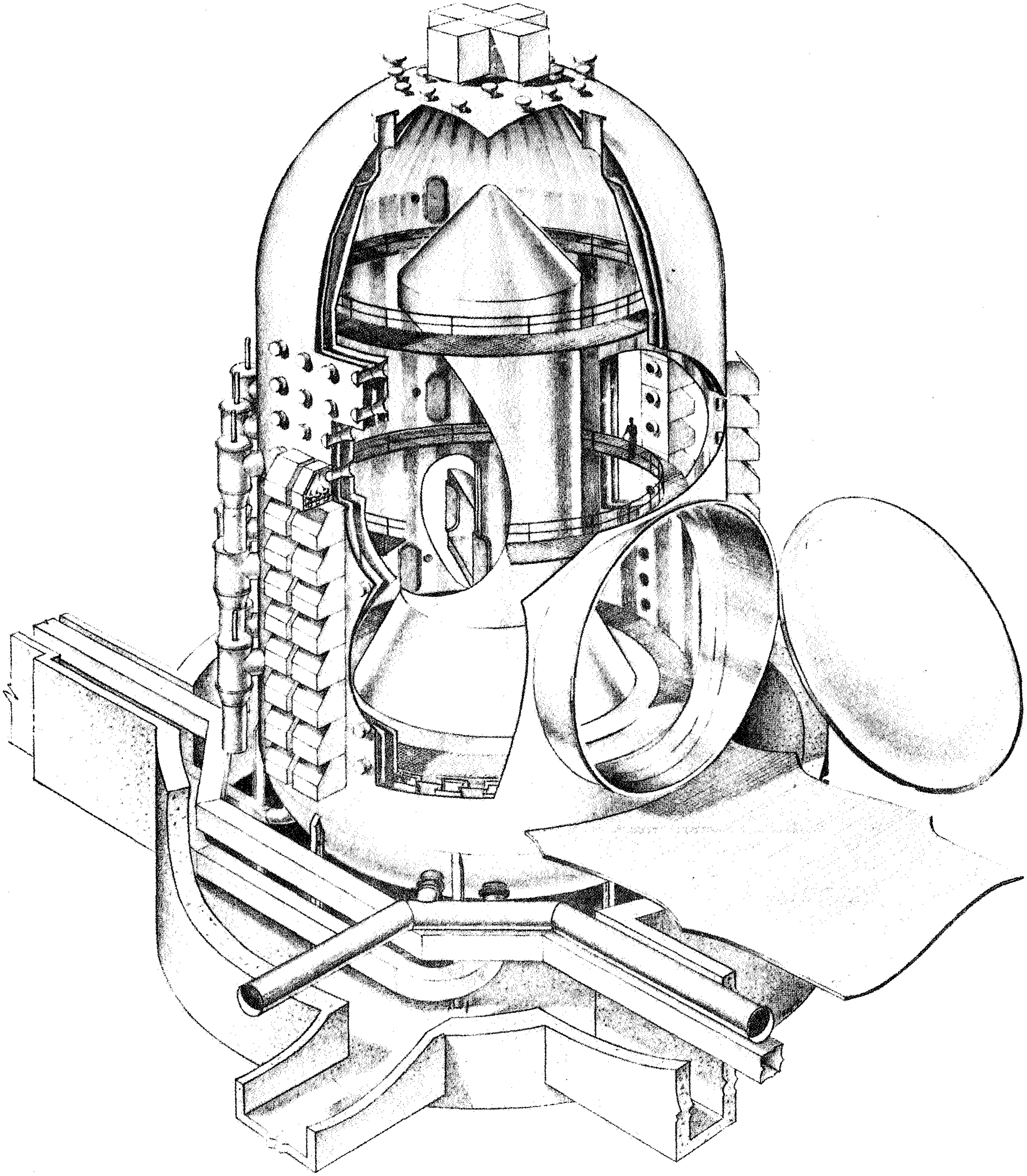
Time to achieve minimum pressure:	24 hours
Actual pumping speed:	100° K Condensables (LN_2) 300 million liters/sec 20° K Condensables (GHe) 3 million liters/sec Diffusion pumps 350,000 liters/sec
Type of pumping system:	Diffusion pumps; cryopumping with liquid nitrogen and helium
Temperature range:	-280 F to +260 F on lunar plane
Type of thermal system:	Electrical strip heaters. +260 F to be held for a maximum of 48 hours during a two-week test period or 2 hours during a 48 hour test period
Area of helium panels:	Approximately 1,180 sq ft; 3,000,000 liters/sec
Solar simulation:	
Area illuminated:	Side sun: 13'x 40' initial, 20' x 65' future Top sun: 13' dia initial, 20' dia future
Maximum intensity:	Controllable between 60 and 137 watts/sq ft with an accuracy of 3 watts/ft^2
Type of lamp:	Carbon arc, auto. feed (RCA)
Degree of collimation:	Half angle of 2°
Uniformity:	± 5% as measured by a 1.0 ft^2 detector ± 10% as measured by a 0.1 ft^2 detector

Other environment capabilities:

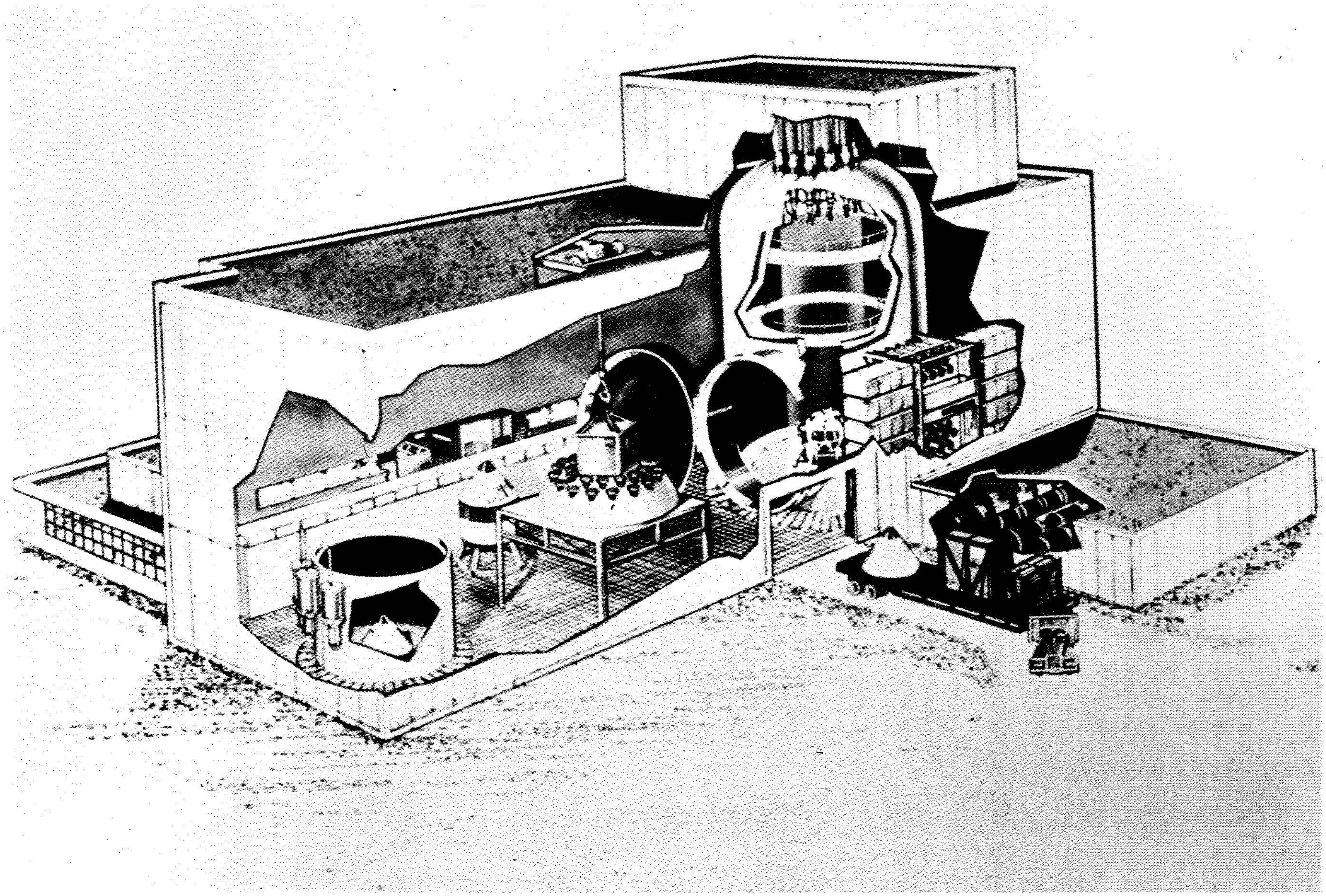
Rotation of specimen:	45' dia rotating table ($\pm$ 180°) at 1-2/3 rpm, 150,000 lbs

Supporting items:

Instrumentation:	1600 channels
Additional information:	Designed to provide uninterrupted test environment for a period of 30 days
Status:	Under construction with completion scheduled for summer 1965



SPACE ENVIRONMENT SIMULATION FACILITY, CHAMBER A
NASA MANNED SPACECRAFT CENTER
HOUSTON, TEXAS



SPACE ENVIRONMENT SIMULATION FACILITY, CHAMBER A

NASA MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

CHAMBER 2

Agency and Location:	NASA Manned Spacecraft Center, Houston, Texas
Name of facility:	Space Environment Simulation Facility, Chamber B
Purpose of facility:	Spacecraft testing and astronaut training
Size & shape of chamber:	35' dia x 41'8" high
Work space dimensions:	20' dia x 20' high plus 9' high truncated conical volume at top. Full 35' dia opening for loading chamber from top.
Maximum size of test article:	13' dia x 27' high; 75,000 lbs
Materials handling equipment:	Yes (50 ton bridge crane with 10 ton auxiliary hoist)
Man-rated:	Yes
Personnel entry locks:	Double manlock at lunar plane level; each lock has 9' x 10' floor area
Type of repressurization system:	1. Repressurize with oxygen and nitrogen from 0 to 6 $\pm$ 1/2 psia total pressure and oxygen partial pressure of 4 $\pm$ 1/2 psi in 30 seconds; pressure can be held at 6 psia; pressurize with air from 6 psia to atmospheric within 60 seconds 2. Repressurize from 10^{-5} torr to 6 psia in 30 minutes 3. Repressurize from 10^{-5} torr to 14.7 psia in 3 hours

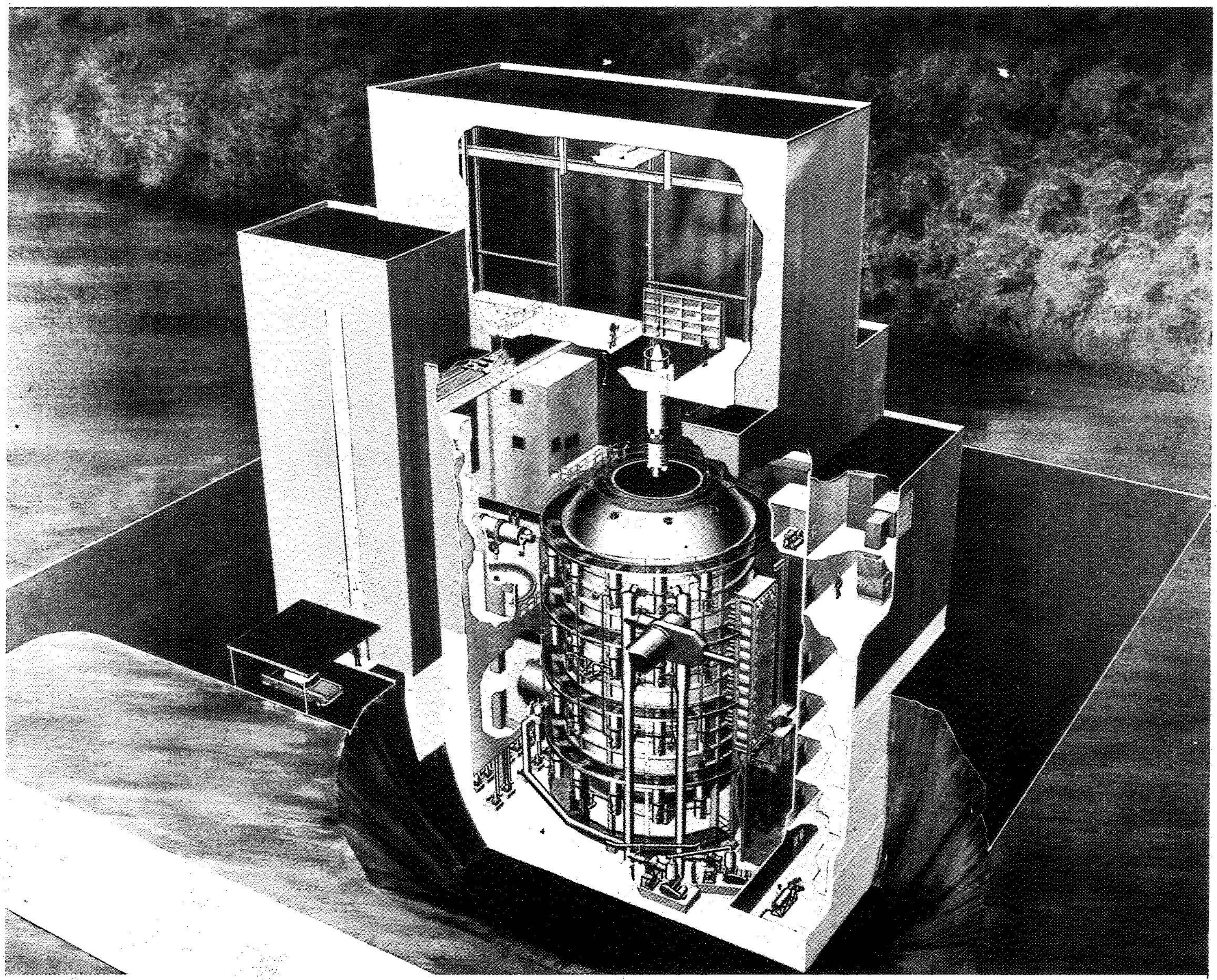
Minimum operating pressure:	10^{-5} torr
Gas load that can be removed at this pressure:	25.7 torr liters/sec
Time to achieve minimum pressure:	3 hours
Type of pumping system:	Diffusion pumps; cryopumping with liquid nitrogen and helium
Temperature range:	-280 F to +260 F
Type of thermal system:	Elec. strip heaters. +260 F to be held for a maximum of 48 hours during a 2-week test period or 2 hours during a 48-hour test period
Solar simulation:	See "Additional Information" below
Area illuminated:	Side sun: None (future or present) Top sun: 5.6'dia initial, 20' dia future
Maximum intensity:	Controllable between 67 and 137 watts/ft^2 with an accuracy of 3 watts/ft^2
Type of lamp:	Carbon arc, auto. feed (RCA)
Degree of collimation:	Half angle of 2°
Uniformity:	± 5% as measured by a 1.0 ft^2 detector ± 10% as measured by a 0.1 ft^2 detector
Other environment capabilities:	
Heat flux:	Elec. strip heaters attached to lunar plane for a +260 F

Supporting items:	
Instrumentation:	1,100 channels
Additional information:	Designed to provide uninterrupted test environment for a period of 30 days. Liquid nitrogen cooled heat sink attached to lunar plane for low temperature. High temperature range obtained by electrical strip heaters.
Status:	Under construction with completion scheduled for summer 1965.

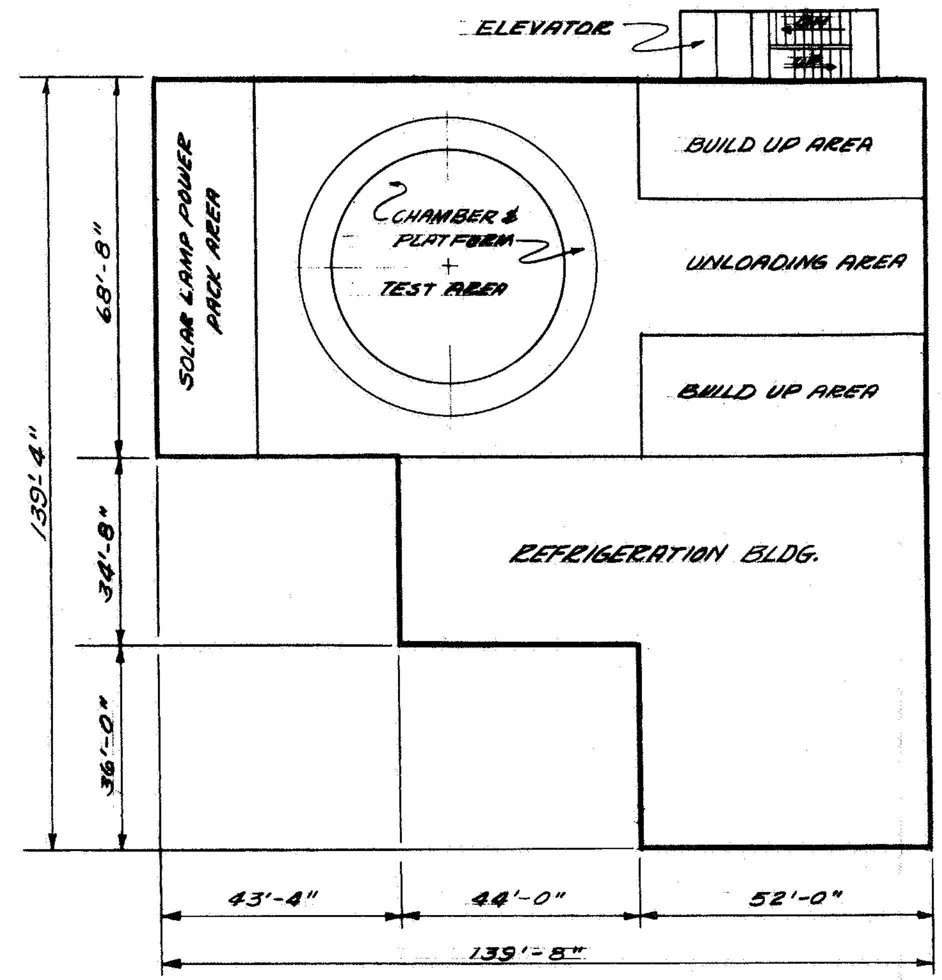
CHAMBER 3

Agency and Location:	U.S. Air Force Arnold Engineering Development Center, Tullahoma, Tennessee
Name of facility:	Aerospace Systems Environmental Chamber, Mark I
Purpose of facility:	Spacecraft testing
Size and shape of chambers:	42' dia x 82' high
Work space dimensions:	35'2" dia x 65' high. 20' dia opening for loading chamber from top
Man-rated:	No
Personnel entry locks:	8' dia on side of chamber
Type of repressurization system:	None
Minimum operating pressure:	10^{-8} torr
Time to achieve minimum pressure:	24 hours
Actual pumping speed:	100°K Condensables (LN_2) 100 million liters/sec 20° K Condensables (GHe) 26 million liters/sec Diffusion pumps 760,000 liters/sec
Type of pumping system:	48 - 32" oil diffusion pumps; cryopumping with liquid nitrogen and helium. One 32" oil diffusion pump in personnel entry lock
Area of liquid nitrogen panels:	Cover 97% of chamber interior; approximately 27,000 sq ft
Area of helium panels:	Approximately 8,160 sq ft
Solar simulation:	
Area illuminated:	6' x 32' or 10' x 18'

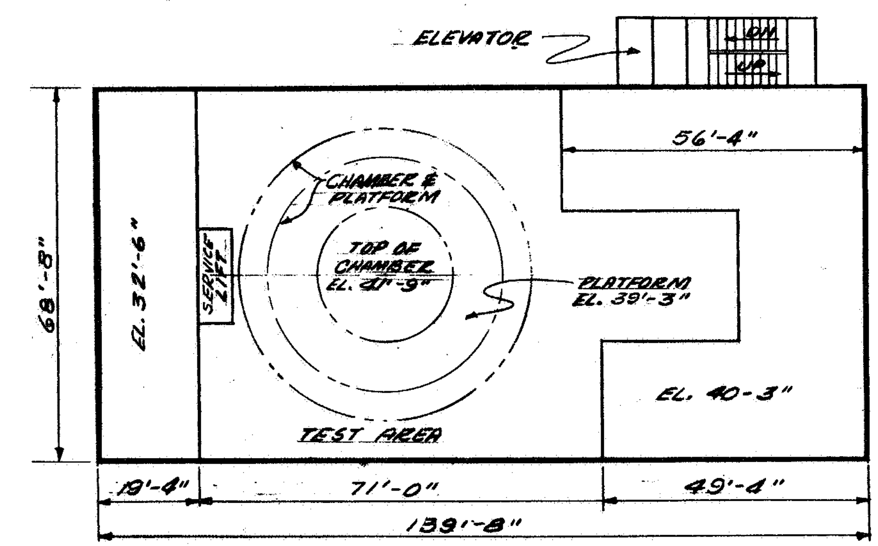
Maximum intensity:	137 watts/sq foot (Based on design data)
Type of lamp:	38 high intensity carbon arc, 32 KW each
Conditions simulated:	Albedo reflectance and earth radiance simulated by quartz lined tubes in a "bird cage"-like arrangement
Type of optical system:	Each lamp has individual optical projection system
Degree of collimation:	40 minutes ± 5 minutes decollimation for half angle
Uniformity:	± 5% over 1 sq ft ± 10% over 0.1 sq ft
Other environment capabilities:	
Vibration:	Four 50,000 lb hydraulic shakers for a 40,000 lb vehicle at 10 to 600 cycles/sec and one electrodynamic shaker with a force output of 1250 lbs up to 2000 cycles/sec with 40,000 lb load. Simulate vibration energy to vehicle by engine operation.
Rotation of specimen:	Simultaneously rotate vehicle in plane of solar array and about its own longitudinal axis
Ascent simulation:	Pump from 760 torr to 30 torr in 80 seconds to simulate launch ascent
Status:	Under construction for completion early 1965. Solar simulation will be available approximately January 1966



AEROSPACE ENVIRONMENTAL CHAMBER, MARK I
ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENNESSEE

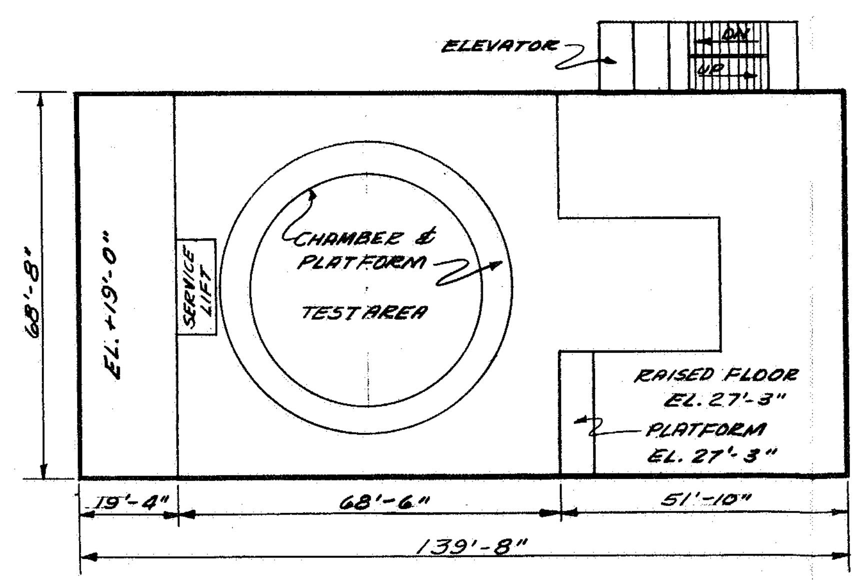


FIRST FLOOR PLAN



THIRD FLOOR PLAN

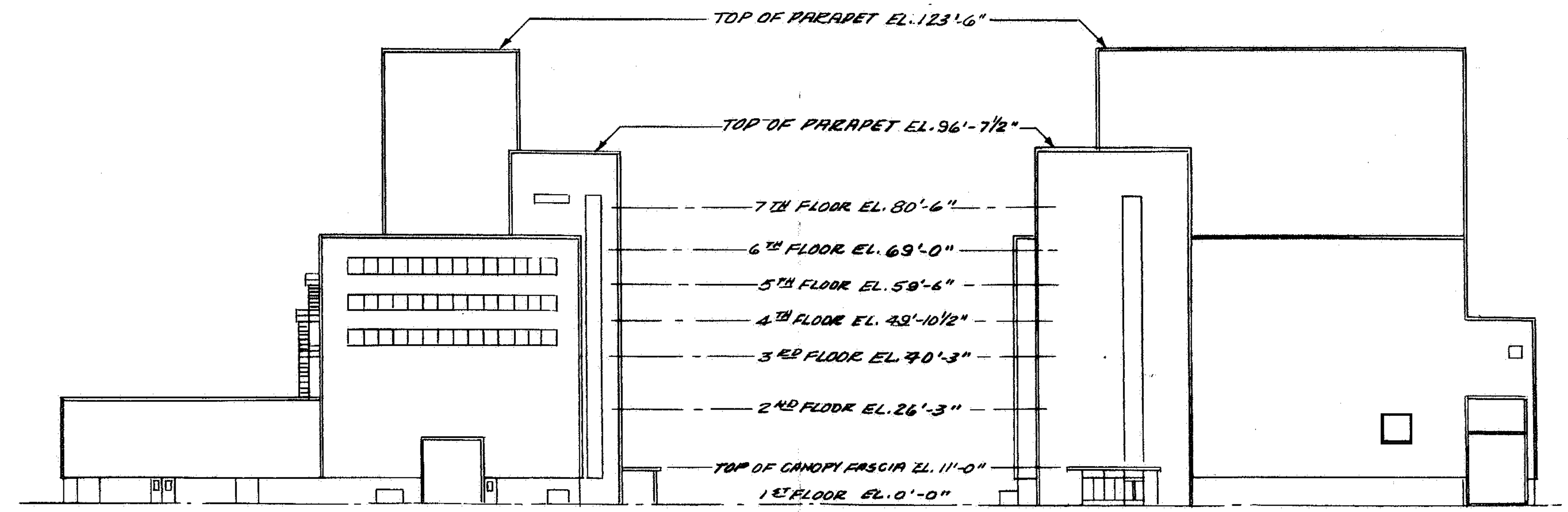
NOTE:
FLOOR PLANS FOR FOURTH, FIFTH, SIX AND SEVENTH FLOORS NOT SHOWN.



SECOND FLOOR PLAN

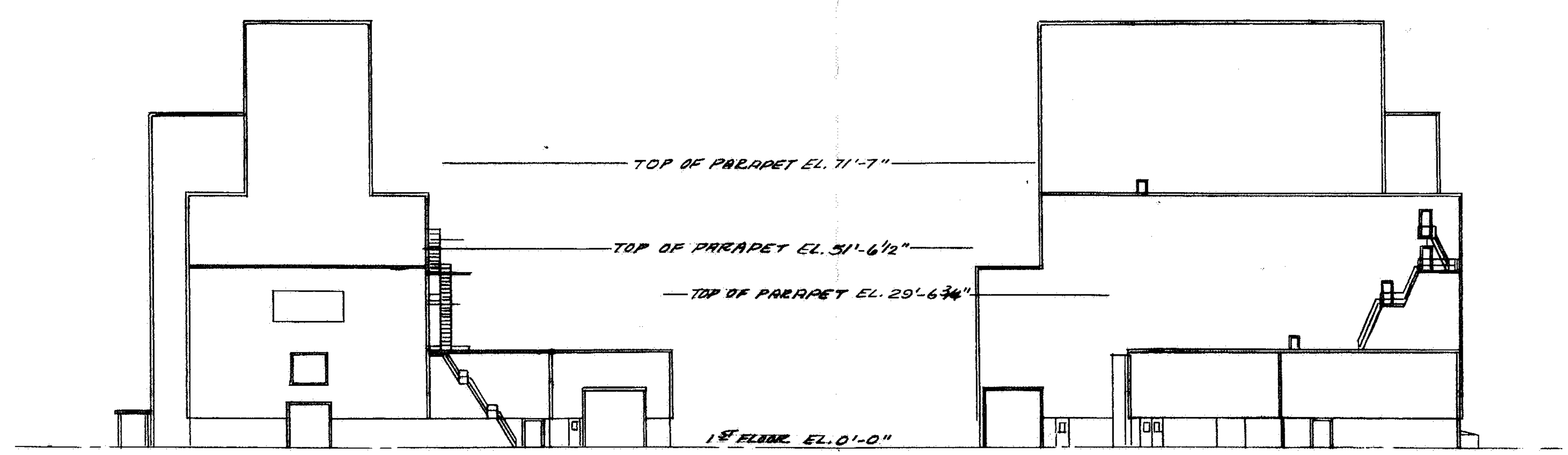
FOLD-OUT #1

CHAMBER 3
APPENDIX C
SKETCH OF AEROSPACE SIMULATOR
MARK I
FLOOR PLANS & ELEVATIONS
(NOT TO SCALE)



NORTH ELEVATION

WEST ELEVATION



SOUTH ELEVATION

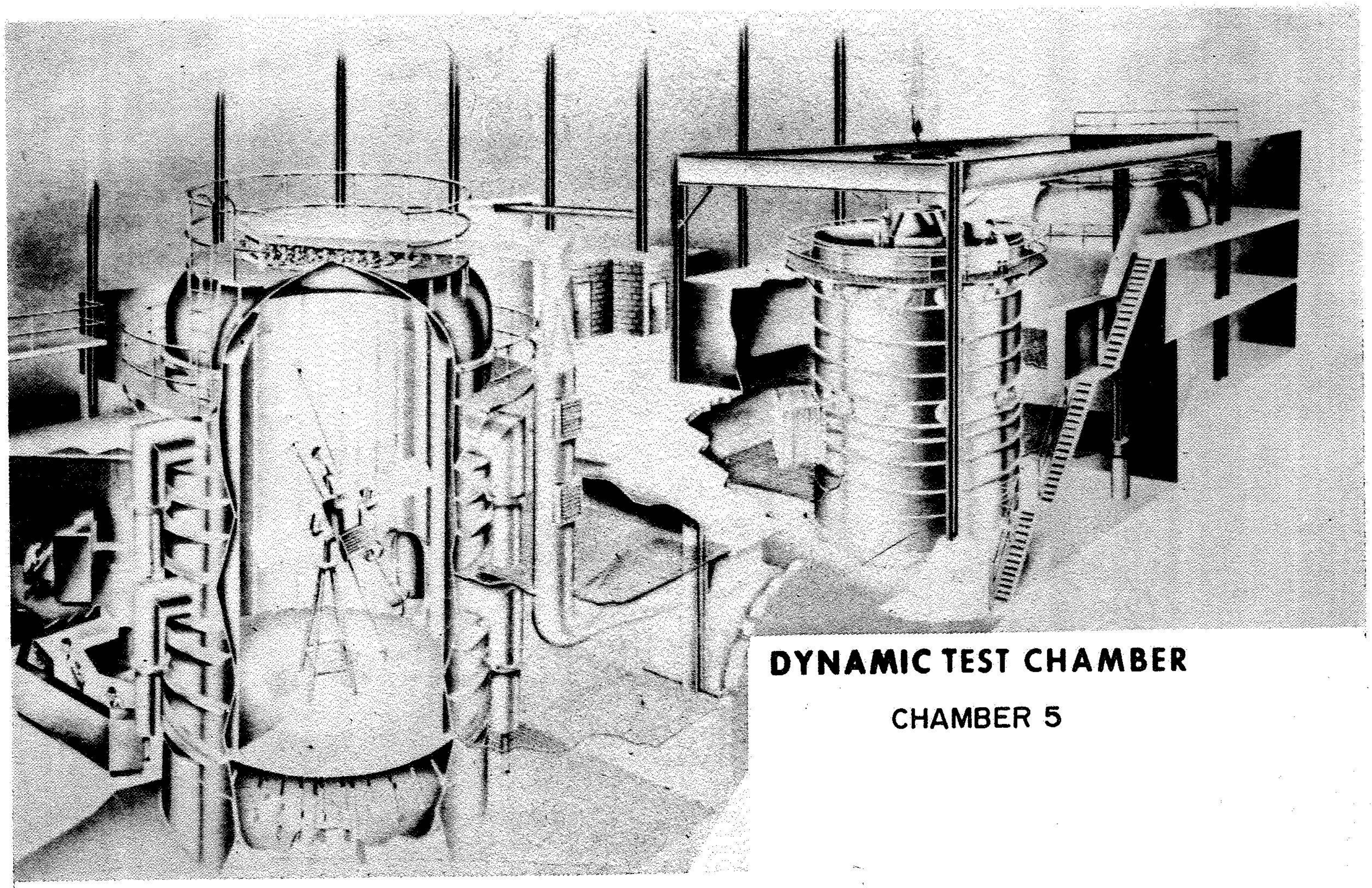
EAST ELEVATION

FOLD-OUT #2

CHAMBER 4

Agency and Location:	NASA Goddard Space Flight Center Greenbelt, Maryland
Name of facility:	Space Environment Simulator
Purpose of facility:	Spacecraft testing
Size and shape of chamber:	35' dia x 60' high
Work space dimensions:	28' dia x 40' high. Full 35' dia opening for loading chamber from top
Materials handling equipment:	Yes
Man-rated:	No
Personnel entry locks:	Yes
Minimum operating pressure:	1 x 10^{-9} torr
Time to achieve minimum pressure:	13 hours
Type of pumping system:	17-32" Diffusion pumps; liquid nitrogen and helium cryopumping
Temperature range:	-320 F to +215 F
Type of thermal system:	Liquid and gaseous nitrogen
Area of liquid nitrogen panels:	Approximately 8,000 sq ft
Area of helium panels:	Approximately 2,000 sq ft
Solar simulation:	
Area illuminated:	18' diameter
Maximum intensity:	Present: 130 watts/sq ft Future: 275 watts/sq ft

Type of lamp:	Mercury-Xenon, 127 lamp module, 2 1/2 KW each
Other environment capabilities:	None
Status:	In operation, including solar simulation



SPACE ENVIRONMENT SIMULATOR AND DYNAMIC TEST CHAMBER
NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

CHAMBER 5

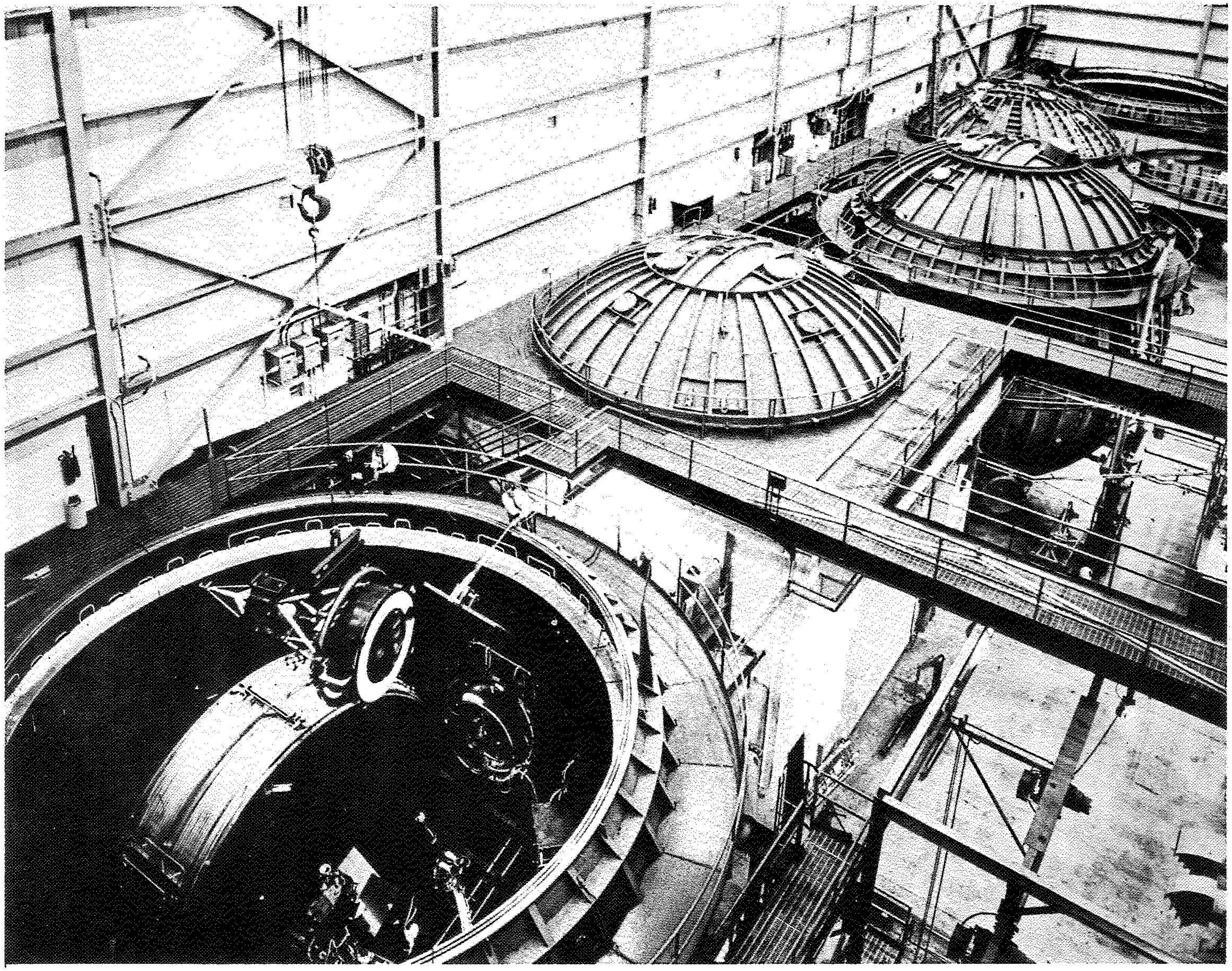
Agency and Location:	NASA Goddard Space Flight Center Greenbelt, Maryland
Name of facility:	Dynamic Test Chamber
Purpose of facility:	Spacecraft testing
Size and shape of chamber:	35' dia x 60' high
Work space dimensions:	28' dia x 40' high. Full 35' dia opening for loading chamber from top
Materials handling equipment:	Yes (overhead crane)
Man-rated:	No
Personnel entry lock:	Yes
Minimum operating pressure:	0.1 torr (Mechanical vacuum pumps only)
Type of pumping system:	Mechanical vacuum pumps. Diffusion pumps can be added at a later date
Type of thermal system:	None. Cold walls can be added at a later date
Solar simulation:	None. Can be added at later date by replacing head on chamber
Other environment capabilities:	Reduction of pressure by mechanical pumps will eliminate the mechanical resistance of the air to rapid motions. Will be used for vibration tests, dynamic balancing, spin-up tests, and solar paddle erection. Can check out control systems employing gas jets for correction of spacecraft orientation.
Status:	In operation.

CHAMBER 6

Agency and Location:	General Electric Valley Forge Space Technology Center, Valley Forge, Pennsylvania
Name of facility:	Thermal Vacuum Chambers of the Space Environment Test Facility
Purpose of facility:	Thermal vacuum qualification and acceptance testing
Size:	Three 39' dia spheres
Work space dimensions:	30' dia spherical volume; 30' dia opening for loading chamber from top
Maximum size of test article:	21' diameter x 30' high; 20,000 lbs
Materials handling equipment:	Yes
Man-rated:	No, but future capability
Personnel entry locks:	One 48" x 96" door in side of chamber
Type of repressurization system:	Controlled dry nitrogen and atmospheric in-bleed
Minimum operating pressure:	1×10^{-9} torr
Time to achieve minimum pressure:	6 hours
Actual pumping speed:	100° K Condensable (LN_2) 3.0×10^8 liters/sec 20° K Condensables (GHe) 3.0×10^6 liters/sec Diffusion pumps 50,000 liters/sec

Type of pumping system:	4-32" diffusion pumps; liquid nitrogen and helium cryopumping
Temperature range:	Cryogenic temperature; -320F to maximum heat flux
Type of thermal system:	Infrared, quartz lamps
Area of liquid nitrogen panels:	3,800 sq ft
Area of helium panels:	1,000 sq ft
Solar simulation:	
Area illuminated:	400 sq ft available in two of the chambers
Maximum intensity:	5-390 watts/sq ft multiple zone controllable
Type of lamp:	Quartz lamp for infrared heating
Conditions simulated:	Solar heating
Uniformity:	$\pm$ 5%
Other environment capabilities:	
Vibration:	Future capability
Shock:	Future capability
Rotation of specimen:	Heat flux programmed test installation provides special supports for 16,000 lbs specimen
Ascent simulation:	Rapid, by use of internal canister
Supporting items:	
Data acquisition (consoles):	Operation only

Instrumentation:	500 copper constantan leads, 150 electrical leads
Usable building area:	Two 1,000 sq ft preparation areas
Additional information:	Continuous testing up to 48 weeks Shutdown and warm-up time is 12 hours.
Status:	In operation



SPACE ENVIRONMENT TEST FACILITY
GENERAL ELECTRIC VALLEY FORGE SPACE TECHNOLOGY CENTER
VALLEY FORGE, PENNSYLVANIA

CHAMBER 7

Agency and Location:	General Electric Valley Forge Space Technology Center, Valley Forge, Pennsylvania
Name of facility:	Solar-Thermal-Vacuum Chamber of the Space Environment Simulation Laboratory
Purpose of facility:	Engineering development; spacecraft and systems test under combined environments of vacuum, cold black space and solar spectrum simulation
Size:	32' dia x 54' high vertical cylinder
Work space dimensions:	27' dia sphere or 20' x 35' Full 32' dia opening for loading chamber from top.
Maximum size of test article:	20' diameter sphere; 44,000 lbs
Materials handling equipment:	Yes
Man-rated:	No, but planned
Personnel entry locks:	One on side of chamber with 40" x 84" opening in chamber
Type of repressurization system:	Controlled dry nitrogen and atmospheric

Minimum operating pressure:	1×10^{-9} torr
Time to achieve minimum pressure:	12 hours
Actual pumping speed:	100° K Condensables (LN_2) 3.4×10^8 liters/sec 20° K Condensables (GHe) 1.6×10^6 liters/sec Non-Condensables (Oil diffusion pumps) 25,000 liters/sec
Type of pumping system:	2 - 32" diffusion pumps; liquid nitrogen and helium cryopumping
Temperature range:	Cryogenic temperature (-320 F) to maximum solar heat
Type of thermal system:	Off-axis solar spectrum simulator
Area of liquid nitrogen panels:	5,400 sq ft
Area of helium panels:	725 sq ft

Solar Simulation:

Area illuminated:	17' dia circle
Maximum intensity:	120 to 140 watts/sq ft. solar spectrum 0.2 to 3 microns (Based on measured data)
Type of lamp:	Xenon, 148 lamps of 5 KW each
Conditions simulated:	Xenon spectrum through quartz optics, albedo and infrared. Mercury-Xenon lamps will be mixed with existing Xenon lamps to improve spectral match.

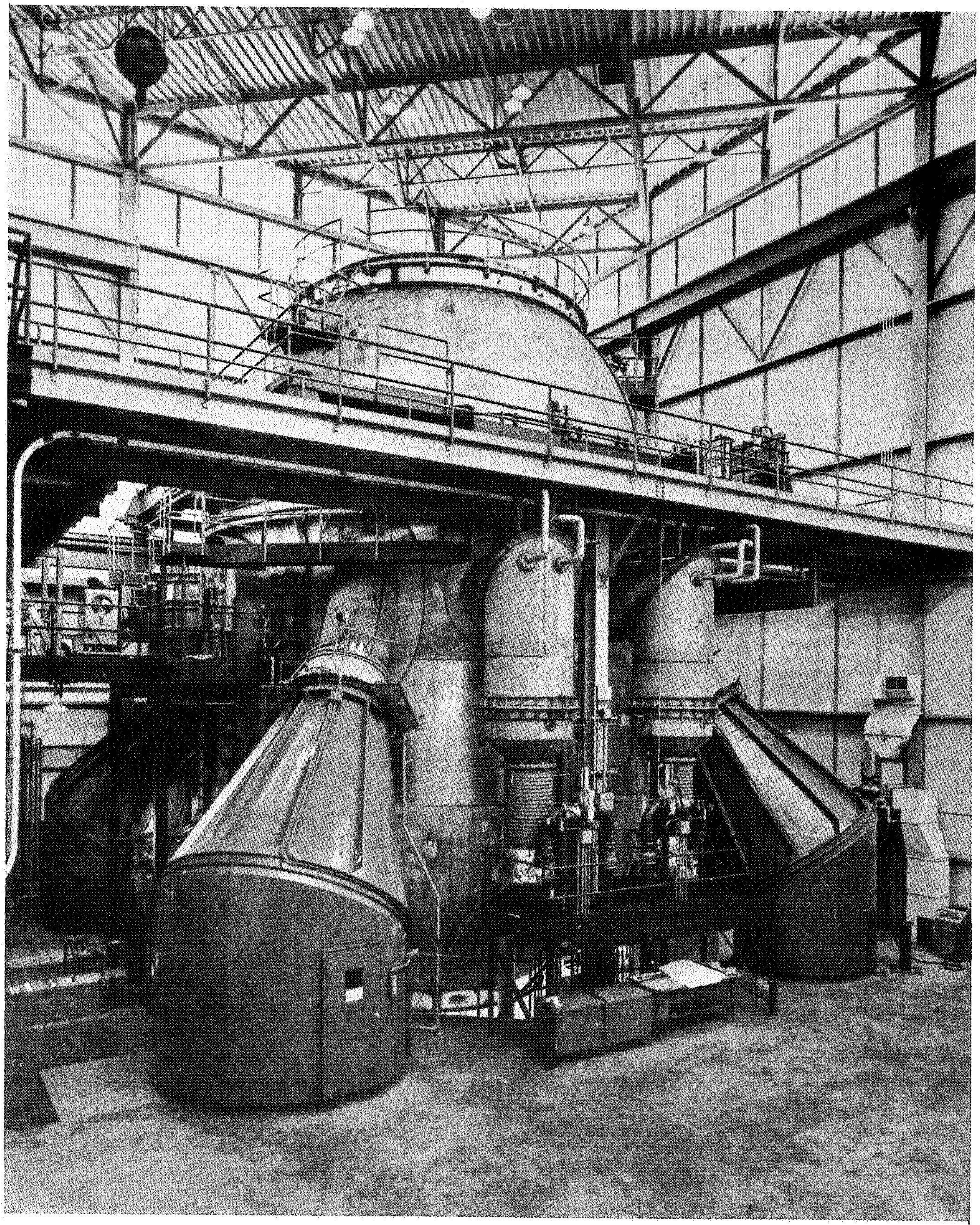
Type of optical system:	Off-axis quadrisected glass mosaic paraboloid - 22' diameter
Degree of collimation:	$\pm$ 2.5° to $\pm$ 3.5° half angle
Uniformity:	$\pm$ 5% over 70% of area $\pm$ 10% over 95% of area

Other environment capabilities:

Vibration:	Future capability
Shock:	Future capability
Heat flux:	Power provided-tailored to vehicle
Rotation of specimen:	2-axis; 5,000 lbs
Ascent simulation:	Rapid, by use of internal canister

Supporting items:

Data acquisition (consoles):	Operation only
Instrumentation:	Approximately 3000 test points can be monitored simultaneously
Usable building area:	5,000 sq ft preparation area
Additional information:	Continuous testing - 2000 hours Shutdown and warmup time is 20-24 hours
Status:	In operation



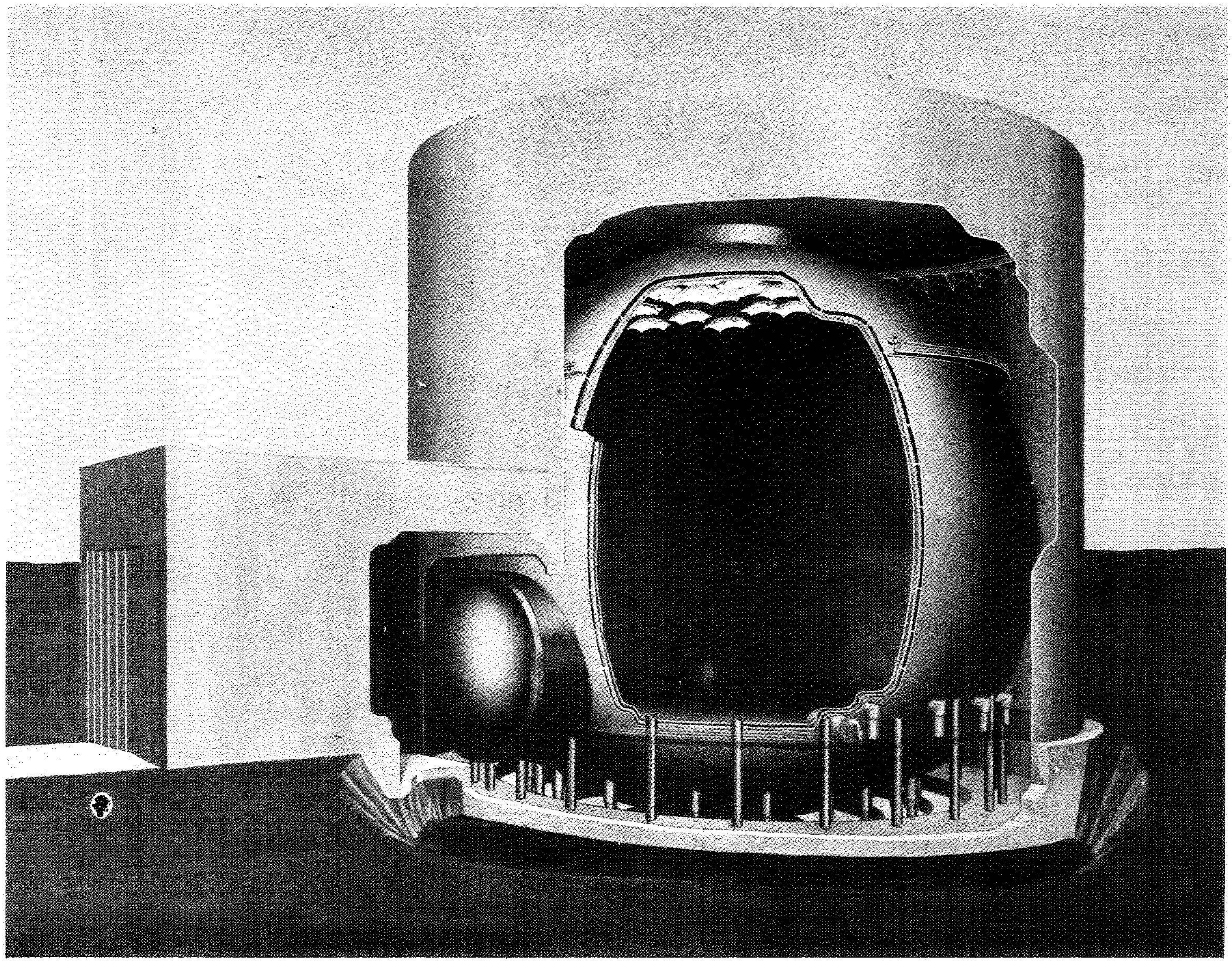
SOLAR-THERMAL-VACUUM CHAMBER
GENERAL ELECTRIC VALLEY FORGE SPACE TECHNOLGY CENTER
VALLEY FORGE, PENNSYLVANIA

CHAMBER 8

Agency and Location:	U. S. Air Force, not sited
Name of facility:	Aerospace Systems Environmental Chamber, Mark IIA
Purpose of facility:	Aerospace vehicle development and reliability testing
Size:	200' ID sphere
Work space dimensions:	190' dia x 170' high
Maximum size of test article:	Limited by entry through 62' dia door (future 70' dia x 130' long vehicle lock)
Materials handling equipment:	Yes
Man-rated:	Yes
Personnel entry locks:	Two with provision for one additional lock.
Type of repressurization system:	Personnel locks pressurized with clean air at normal rate of 25-50 torr/second with emergency over-ride of 150 torr/second
Minimum operating pressure:	10^{-8} torr
Actual pumping speed:	$100^{\circ}K$ Condensables (LN_2) 2,000 million liters/sec 20° K Condensables (GHe) 200 million liters/sec Diffusion pumps 2.5 million liters/sec

Type of pumping system:	Diffusion pumps; cryopumping with liquid nitrogen and helium
Temperature range:	$-320^{\circ}F$ Working floor refrigerated by liquid nitrogen
Solar simulation:	
Area illuminated:	60' dia (future 150' dia); fixed location on top of chamber
Maximum intensity:	130 watts/sq ft (future 260 watts/sq ft)
Degree of collimation:	Half angle of 1°
Conditions simulated:	Albedo reflectance and earth radiance to be simulated by "bird cage" like arrangement
Uniformity:	$\pm$ 5% averaged over any 10 sq inches of the 60' dia field
Other environment capabilities:	
Heat flux:	By radiant heating shrouds-future expanded facility
Rotation of specimen:	Gimbal - 2 degree freedom Vehicle mount will provide for rotation of approx 55' wide x 105' long, 265,000 lb test vehicle in the radiation field of the fixed solar simulator
Supporting items:	
Data acquisition (consoles):	Yes
Instrumentation:	5,000 channels, approx

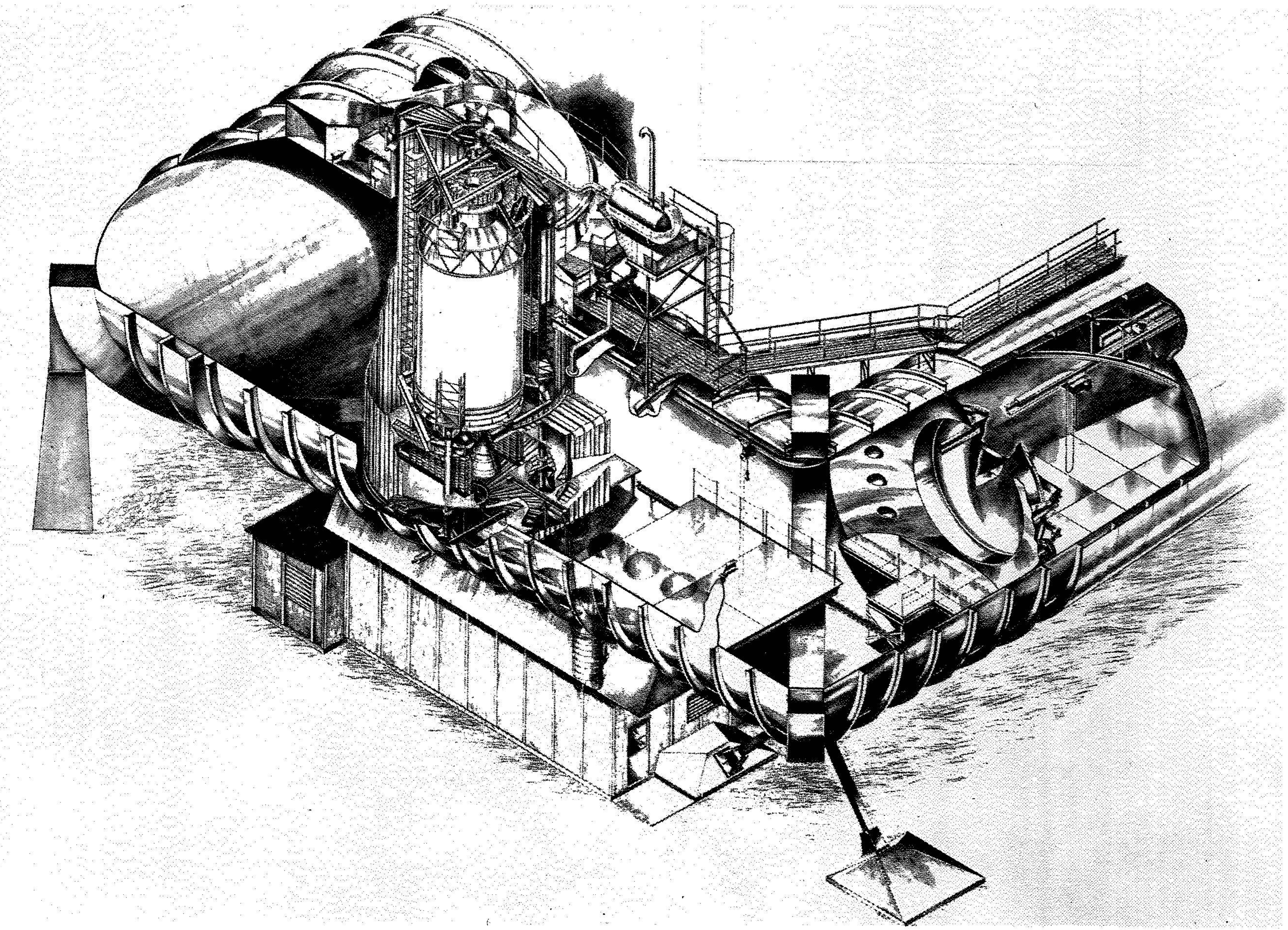
Biomedical laboratory:	Yes
Usable building area:	38,000 ft^2 for vehicle preparation
Additional information:	Aluminum being considered for chamber shell and cryogenic surfaces to reduce activation (nuclear provisions)
	Provision for later inclusion of nuclear vehicles of 3 MWT reactor potential
	Electrical and attitude jets for propulsion
	Design of all components of the solar simulation system to be based on continuous test operation for 11 months with minimum shut-down for maintenance of critical components such as radiation sources.
	Personnel capsules designed for two men with provisions for rescue of a third person will move within the chamber and will serve as observation posts, maintenance centers and emergency rescue vehicles.
	In addition to the future vehicle lock, provisions are to be made for an additional lock similar to the large vehicle lock located on the same axis and directly opposite.
Status:	Facility proposed; not funded. Chamber when initially constructed will have essentially vacuum capability; other capabilities to be added incrementally as required.



CHAMBER 8
AEROSPACE SYSTEMS ENVIRONMENTAL CHAMBER MARK II A

CHAMBER 9

Agency and location:	NASA Lewis Research Center 21000 Brookpark Road Cleveland 35, Ohio
Name of facility:	Centaur Environmental Test Space Power Chamber
Size:	30' dia x 100' long portion of altitude wind tunnel converted to space chamber Approx 22' dia opening for loading chamber from top
Minimum operating pressure:	2 x 10^{-6} torr
Time to achieve minimum pressure:	24 hours with chamber empty
Solar simulation:	Albedo only. Solar radiation could be provided by adding dome to the top of the tunnel
Temperature range:	30' dia thermal shroud liquid nitrogen cooled
Special features:	Remainder of altitude tunnel could be converted to space chamber also. Limited by carbon steel walls. Conversion of remainder of tunnel will require additional shop space
Status:	In operation



CENTAUR ENVIRONMENTAL TEST SPACE POWER CHAMBER
LEWIS RESEARCH CENTER
CLEVELAND, OHIO

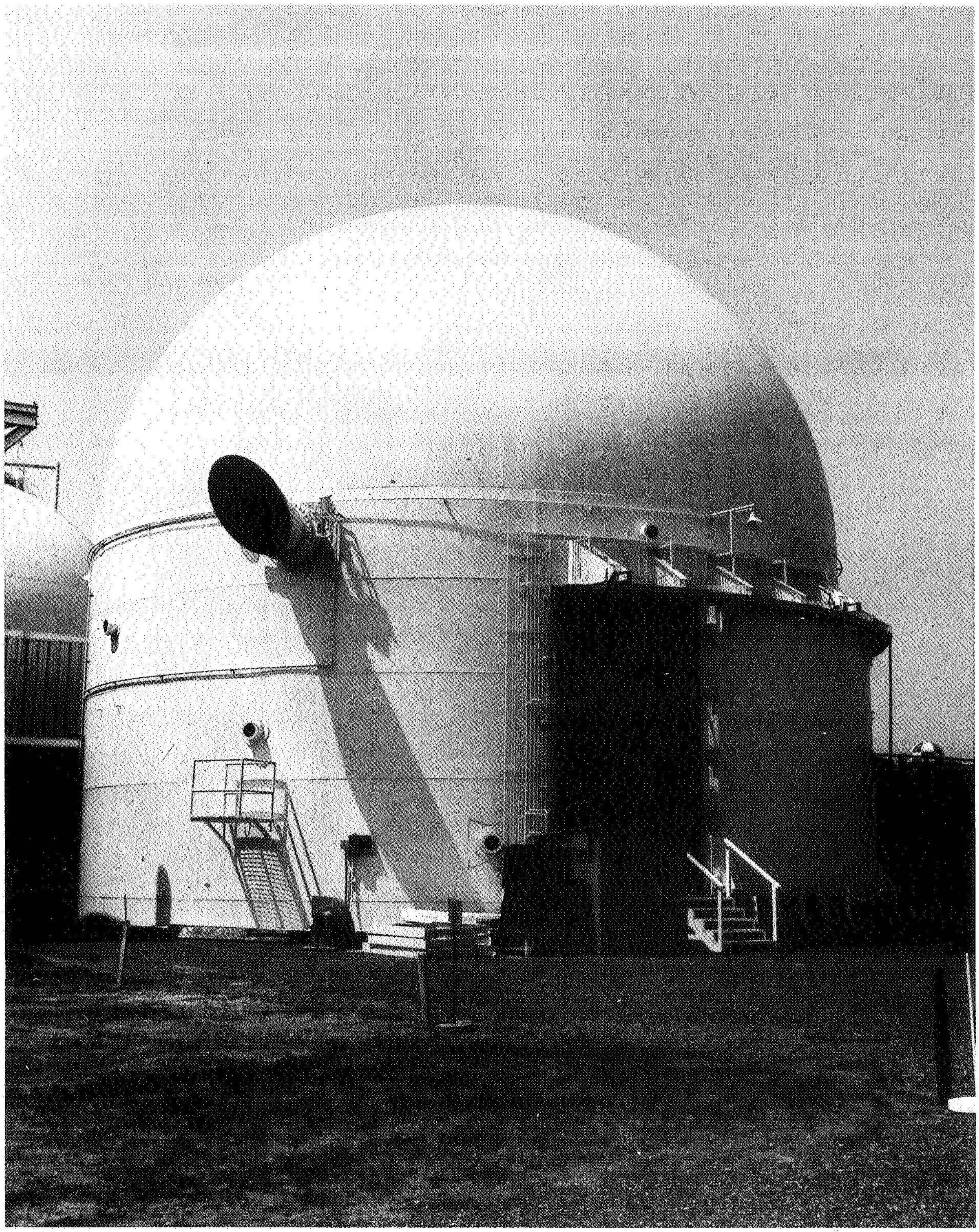
CHAMBER 10

Agency and Location:	NASA Marshall Space Flight Center, Huntsville, Alabama
Purpose of facility:	Test Saturn guidance instrumentation ring
Size:	40' dia x 80' high
Work space dimensions:	34' dia
Maximum size of test article:	33' dia x 60' high
Man-rated:	Yes
Personnel entry locks:	Yes
Minimum operating pressure:	1×10^{-8} torr
Type of pumping system:	Diffusion; 4 K and 77 K cryosurface
Actual pumping speed:	Gaseous helium at 300,000-400,000 liters/sec
Temperature range:	4 K to 77 K
Type of thermal system:	LN_2
Solar simulation:	Planned
Uniformity:	10-15% This is satisfactory since Saturn ring is aluminum which is a good conductor of heat
Other environment capabilities:	Heat flux only. Possible means of rotation of test article in two planes
Status:	Inactive - no longer proposed

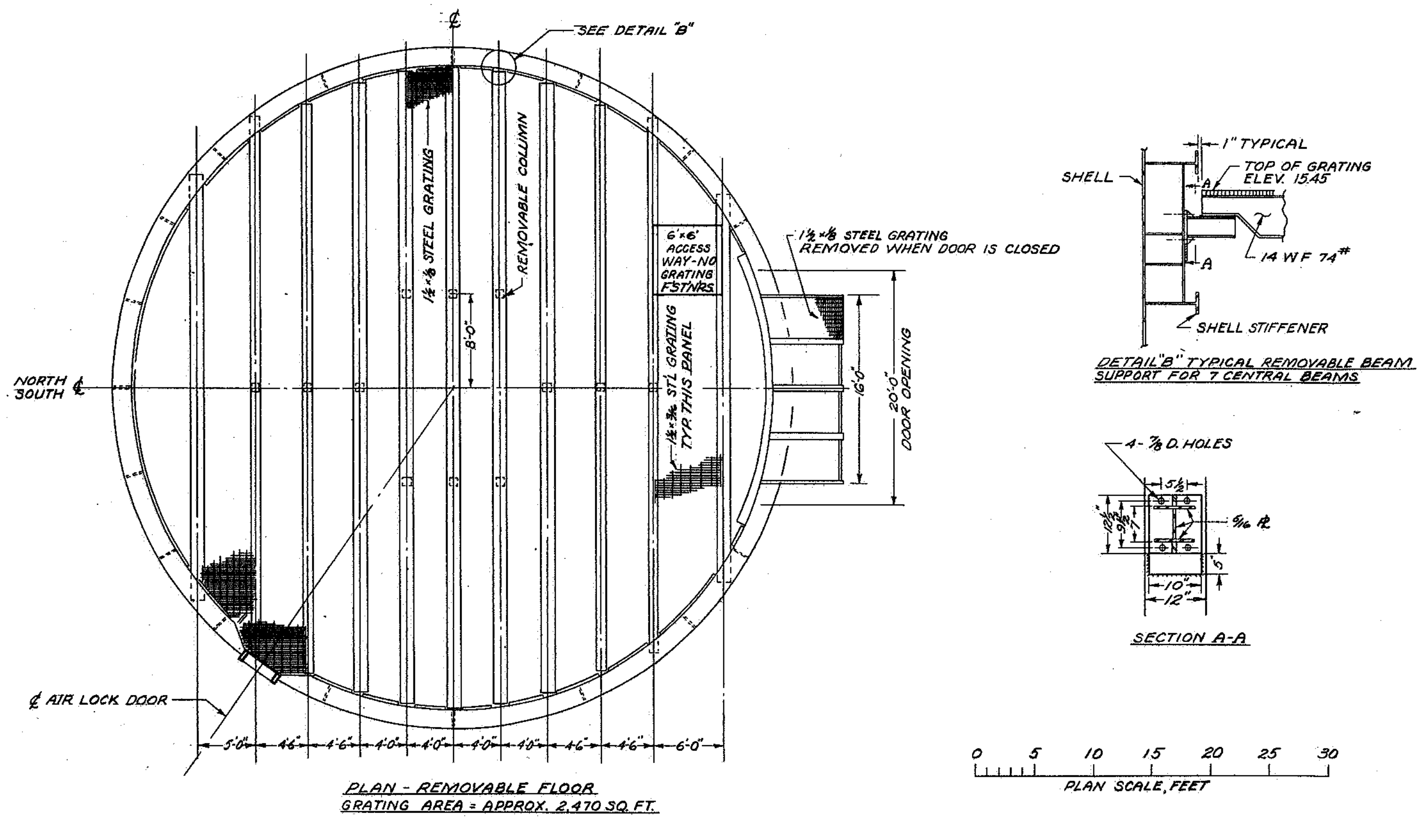
CHAMBER 11

Agency and Location:	NASA Langley Research Center Hampton, Virginia
Name of facility:	Dynamics Research Laboratory,DLD
Purpose of facility:	Research on spacecraft structures, materials and equipment
Size:	55' dia vertical cyliner, 20' x 20' side opening door
Work space dimensions:	55' dia, 55' clear height at center of chamber above removable floor
Maximum size of test article:	2,000 lbs on centrifuge; additional weight on removable floor when centrifuge is not used
Materials handling equipment:	Yes (removable 5-ton crane on interior of chamber)
Man-rated:	Potentially - yes
Personnel entry lock:	Yes - 4-person capacity
Type of repressurization system:	Outside air-quick repressurization from 10^{-1} torr to 1 atmosphere in 30 secs
Minimum operating pressure:	10^{-2} torr (10^{-4} torr after installation of four 32" diffusion pumps by 1 Jan 65)
Gas load that can be removed at this pressure:	4,000 cfm minimum at 10^{-1} torr
Time to achieve minimum pressure:	135 minutes to reach 10^{-1} torr

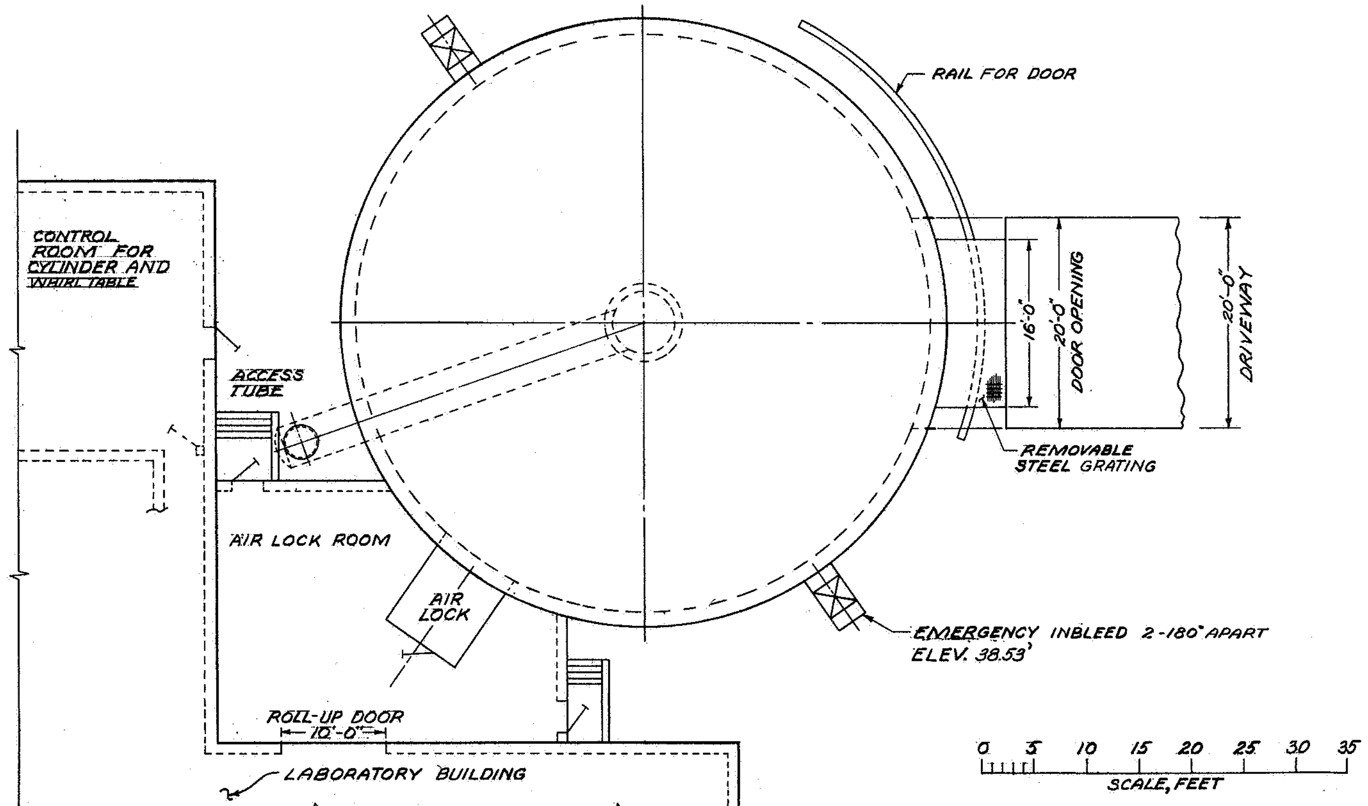
Type of pumping system:	Mechanical pumps initially with diffusion pumps in future
Temperature control:	None. No cryogenic shrouds Chamber has carbon steel walls.
Solar simulation:	None
Other environment capabilities:	
Centrifuge:	Centrifuge 0.5 G to 100 G, 50,000 G-lbs capacity, maximum specimen weight 2,000 pounds. Mounting faces at 16.5' radius or 20.5' radius
Vibration:	3,000 lb hydraulic shaker 0-500 cps, ± 0.5 inches
Status:	In operation for space station work



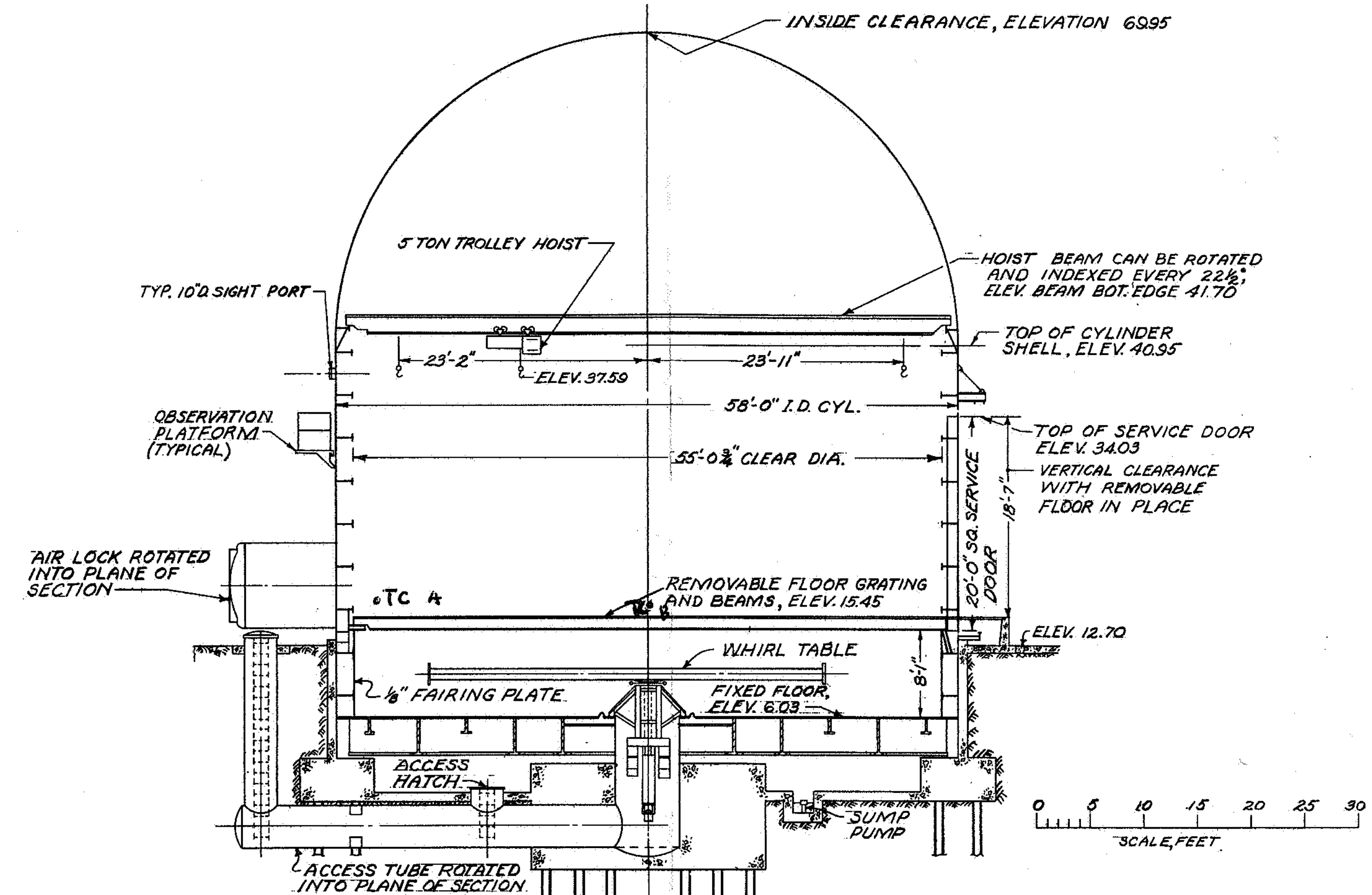
CHAMBER II
DYNAMICS RESEARCH LABORATORY
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA



CYLINDER AND WHIRL TABLE - LOCATION OF REMOVABLE FLOOR BEAMS AND GRATINGS IN CYLINDER



CYLINDER AND WHIRL TABLE. PLAN VIEW OF GENERAL ARRANGEMENT



CYLINDER AND WHIRL TABLE - SECTION THRU CYLINDER LOOKING EAST

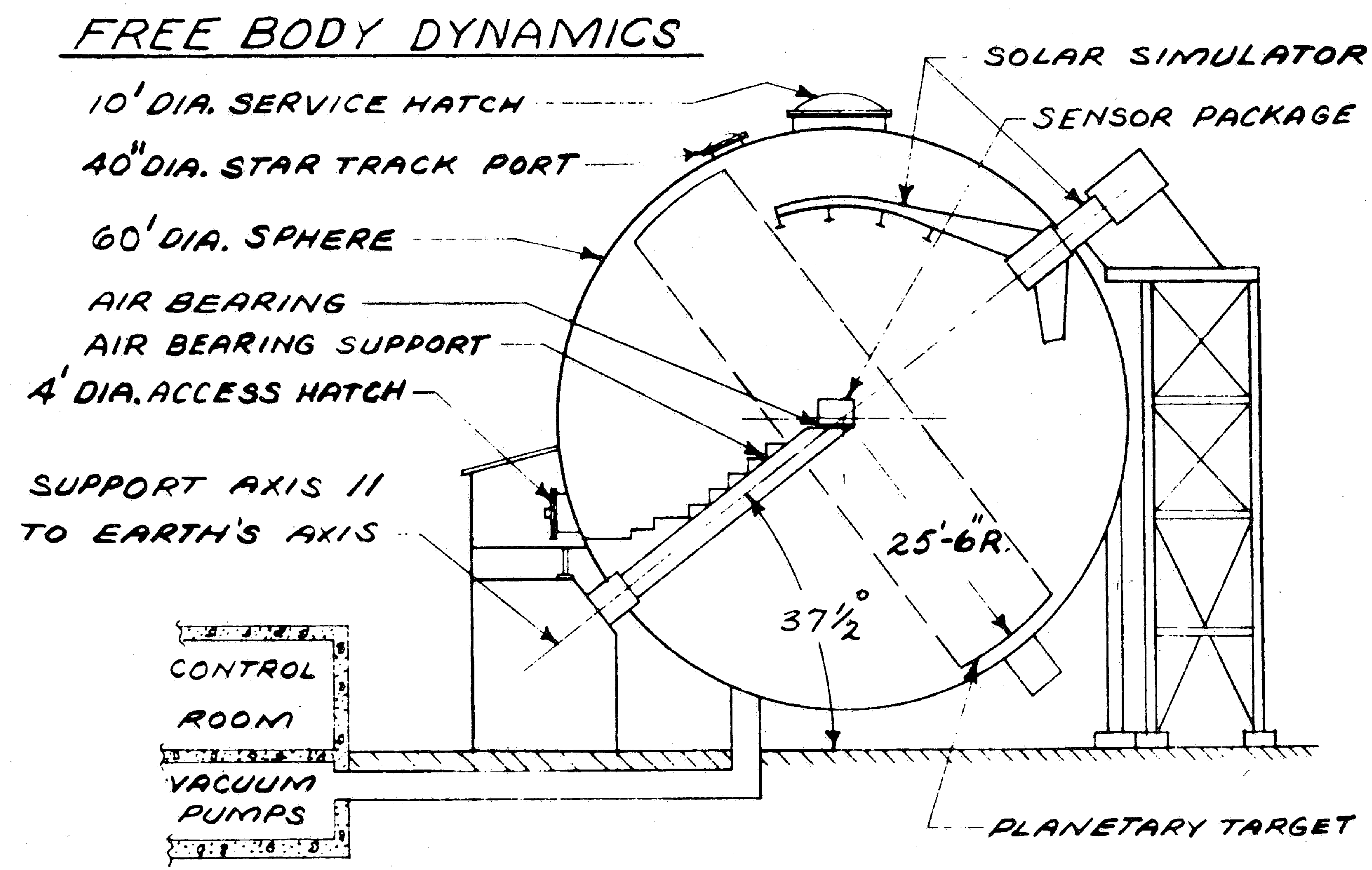
CHAMBER II
DYNAMICS RESEARCH LABORATORY

NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

C-73

CHAMBER 12

Agency and location:	NASA Langley Research Center Hampton, Virginia
Name of facility:	Free Body Dynamics Chamber, Dynamics Research Laboratory
Size:	60' dia sphere, 10' dia service hatch
Maximum size of test article:	40' dia spherical volume around air bearing support; 4,000 pounds
Man-rated:	No
Personnel entry locks:	No
Minimum operating pressure:	2×10^{-1} torr
Time to achieve minimum pressure:	6 hours
Type of pumping system:	Mechanical pumps
Temperature range:	10 to 70 F above sphere wall temperature. No cryogenic shrouds since chamber has carbon steel walls
Solar simulation:	
Area illuminated:	30" dia sun. Rotational rate 15^{o}/hr; azimuth angles 30^{o}, 45^{o}, 60^{o}, 75^{o}, 90^{o}
Other environment capabilities:	Rotation of planetary target at rate of one rpm to one revolution per day
Status:	Under construction with completion early 1965


FREE BODY DYNAMICS
10' DIA. SERVICE HATCH
40" DIA. STAR TRACK PORT
60' DIA. SPHERE
AIR BEARING
AIR BEARING SUPPORT
4' DIA. ACCESS HATCH
SUPPORT AXIS // TO EARTH'S AXIS
SOLAR SIMULATOR
SENSOR PACKAGE
25'-6" R.
37½°
CONTROL ROOM
VACUUM PUMPS
PLANETARY TARGET

FOLD-OUT #1

VACUUM: 2×10^{-1} MM. HG IN 6 HOURS

TEST VEHICLE: MAX. WT. 4,000 LBS., SIZE LIMITED TO 40 FT. SPHERICAL DIA. VOLUME AROUND AIR BEARING SUPPORT.

SOLAR SIMULATOR: ROTATIONAL RATE, 15°/HR.; AZIMUTH ANGLES, 30°, 45°, 60°, 75°, 90°; SUN DIAMETER, 30 IN.

PLANETARY TARGET: ROTATIONAL RATES, 1 R.P.M. TO 1 R.P. DAY; DIAMETER, 20 FT. TEMPERATURE, CONTROLLABLE FROM 10° TO 70° ABOVE SPHERE WALL TEMP.

ELECTRICAL LEADS:

MODEL SUPPORT: 50-600 V.-5A. SH. INSTR LEADS; 2-28 V.-20 A. DC.; 4-110 V.-20 A. 400 CY. A.C.; 2-R.F. 25 WATT; 2-110 V.-20 A. 60 CY. A.C.;

TELEMETRY CHANNELS, SENSOR PACKAGE TO CONTROL ROOM: 10 ON-OFF; 5 ANALOG, 2½ V., 0-10 CPS; 2 ANALOG 10 MV, 0-10 CPS; 2 ANALOG, 2½ V, 0-600 CPS.

TEST CELL FEATURES: 4'×4'-4"×32' VIBRATION FREE BEAM, 15" DIA. MODEL SOLAR SOURCE, TELEMETRY TIE-IN WITH CONTROL ROOM.

CHAMBER 12
DYNAMICS RESEARCH LABORATORY
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

FOLD-OUT #2

CHAMBER 13

Agency and location:	NASA Langley Research Center, Hampton Virginia
Name of facility:	Space Systems Research Laboratory
Purpose of facility:	Research and full-scale tests on over-all manned and unmanned systems for use in orbiting research laboratories and lunar bases
Size:	60' dia x 60' high
Man-rated:	Yes
Personnel entry locks:	Yes
Minimum operating pressure:	10^{-5} torr
Temperature range:	-270 F to ambient
Type of thermal system:	Quartz lamps with para bolic reflectors
Solar simulation:	
Area illuminated:	500 sq ft
Maximum intensity:	130 watts/sq ft (based on design data)
Type of lamp:	Quartz
Conditions simulated:	Heat flux
Status:	Proposed as FY 65 budget item

CHAMBER 14

Agency and location:	Douglas Aircraft Company Douglas Space Systems Center Huntington Beach, California
Name of facility:	Space Simulation Laboratory
Purpose of facility:	Earth orbit simulation facility designed solely for research and developmental testing of launching and spacecraft vehicles, space systems.
Size:	39' dia sphere, 30' dia door
Work space dimensions:	30' dia spherical volume; 20' dia flat bedplate bottom (see below)
Maximum size of test article:	Limited to entry through 30' dia door. Chamber designed for addition of 20' future "spool" extension to give 50' vertical clearance dimension capability.
Materials handling equipment:	25 ton and 5 ton bridge cranes plus platforms, scaffolds, chainfalls, lifts, etc.
Man-rated:	Recompression provision includes quick open door for man lock and 20 second recompression. Man-rating system under development - scheduled operational, 1965.
Personnel entry locks:	Yes (see above)
Type of repressurization System:	High pressure dry nitrogen gas and high pressure dry air
Minimum operating pressure:	Below 5×10^{-10} torr (with test specimen in chamber)
Time to achieve minimum pressure:	Less than 8 hours (with test specimen in chamber)

Actual pumping speed:	Acceptance tests demonstrated 6 million liters per second dry nitrogen pumping capability at 1 x 10^{-6} torr. This is net pumping speed of gas introduced from the outside of the chamber. Design requirement of 3 million liters per second was substantially exceeded by changes of geometry and operating temperatures of the cryogenic array. The chamber's present configuration utilizes only approximately 1/2 of the area available for cryopumping. The helium refrigeration plant already installed is approximately 3 times the required capacity so expansion or increase is relatively simple and economical.
Type of pumping system:	4 - 35" oil diffusion pumps; liquid nitrogen and 13 to 20K helium cryopumping.
Temperature range:	80 K to 100 K optically tight shroud, can be heated to 300 F.
Type of thermal system:	Infrared heating and quartz lamp arrays with ignitron controllers. Hot gas system for thermal shroud under development.
Solar simulation:	Under construction; expected to be operational November 1964.
Area illuminated:	Provision for future 20' dia or 4' dia 140 watts/sq ft. 4' dia solar simulator beam may be directed into man lock or projected into 39' sphere, through man lock.
Maximum intensity:	190 watts per sq ft upgradable to 270 watts per sq ft(variable from 50 watts/sq ft)

Type of lamp:	Xenon compact arc (5 Kilowatts)
Uniformity:	± 5%

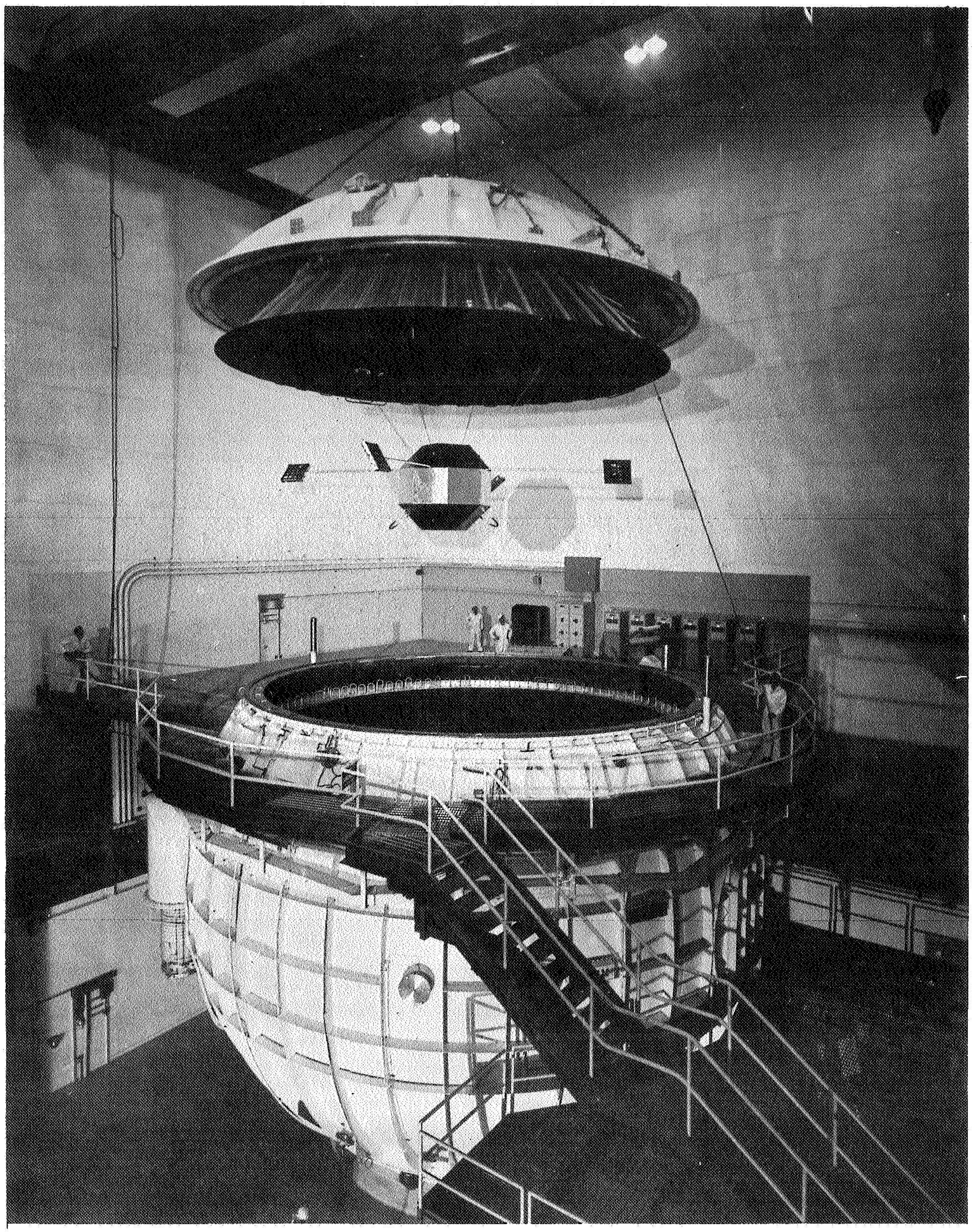
Other environment capabilities:

Vibration and shock:	Chamber is built with a 20' dia flat Ferromagnetic stainless steel bedplate supported on a 1-1/2 million pound reaction block which can accommodate special high vacuum shakers (8-6,000# force shakers) or shock testers, drop testers, centrifuge, gimballing or rotation equipment - provisions only.
Heat flux:	Programmed infrared (10 channels or zones) ignitron controllers.
Rotation of specimen:	Same as vibration and shock above.
Ascent simulation:	Man rating configuration will permit programmed ascent of the 10' dia x 16' long primary air lock. Steam ejector is being considered for the 39' sphere.

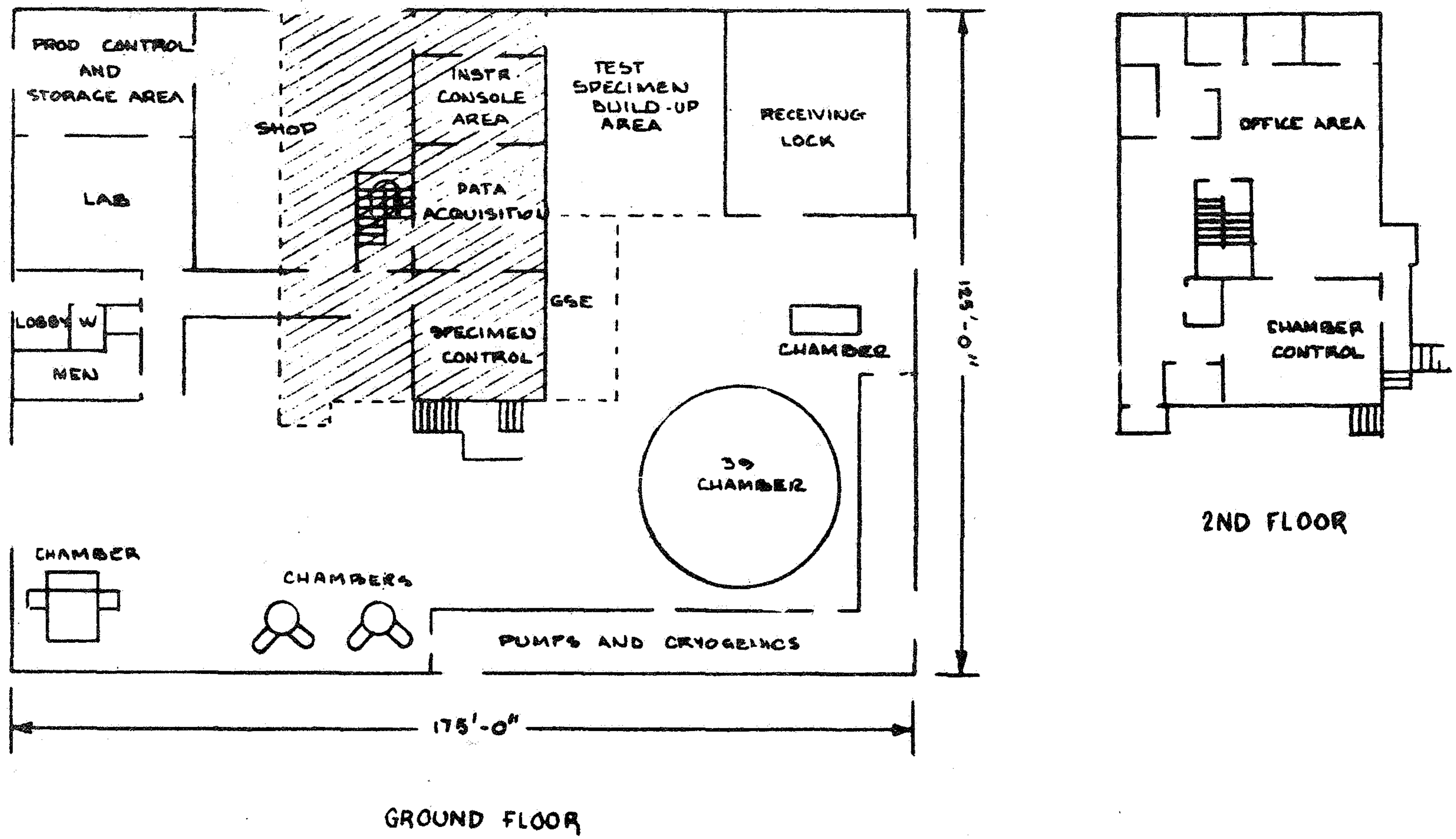
Supporting items:

Data acquisition (Consoles):	200 channel punch paper tape system (scan rate one data pt/chan/30 sec). Null balance type recorders (72 channels). Currently being installed 70 channel multiplexer with AD converter. Magnetic tape logging (scan rate = 5 data pts/sec/channel) + simultaneous monitoring capability. Lab is hard wired to central computing station for data analysis. Central computing station includes: IBM 7094 (1) IBM 1401 (2) SDS 920 (1) Additional computer station (data engineering): CDC 924A (1) CDC 160A (1) Additional computer station (ED & SIL) CDC 924A (2)

	The above equipment can be tied into as necessary (already installed or installation scheduled) Additional equipment (oscillographs, etc.) are obtained from other labs. Further upgrading under consideration.
Instrumentation:	Reflectometer, emissometer, spectral radiometer, high vacuum and cryogenic instrumentation, etc.
Additional information:	Mass spectrometer gas analyzers, helium mass spectrometer leak detectors, Vacuum Stds Corp. dynamic vacuum gage calibrator,"In-situ" vacuum gage calibrator, bell jars, ultrasonic cleaners, pump stands, thermal control loops, etc. 30,000 sq ft clean air-conditioned laboratory with personnel and test specimen air locks for entry. Building is modular in construction and expandable.
Status:	Operational and being upgraded as noted.

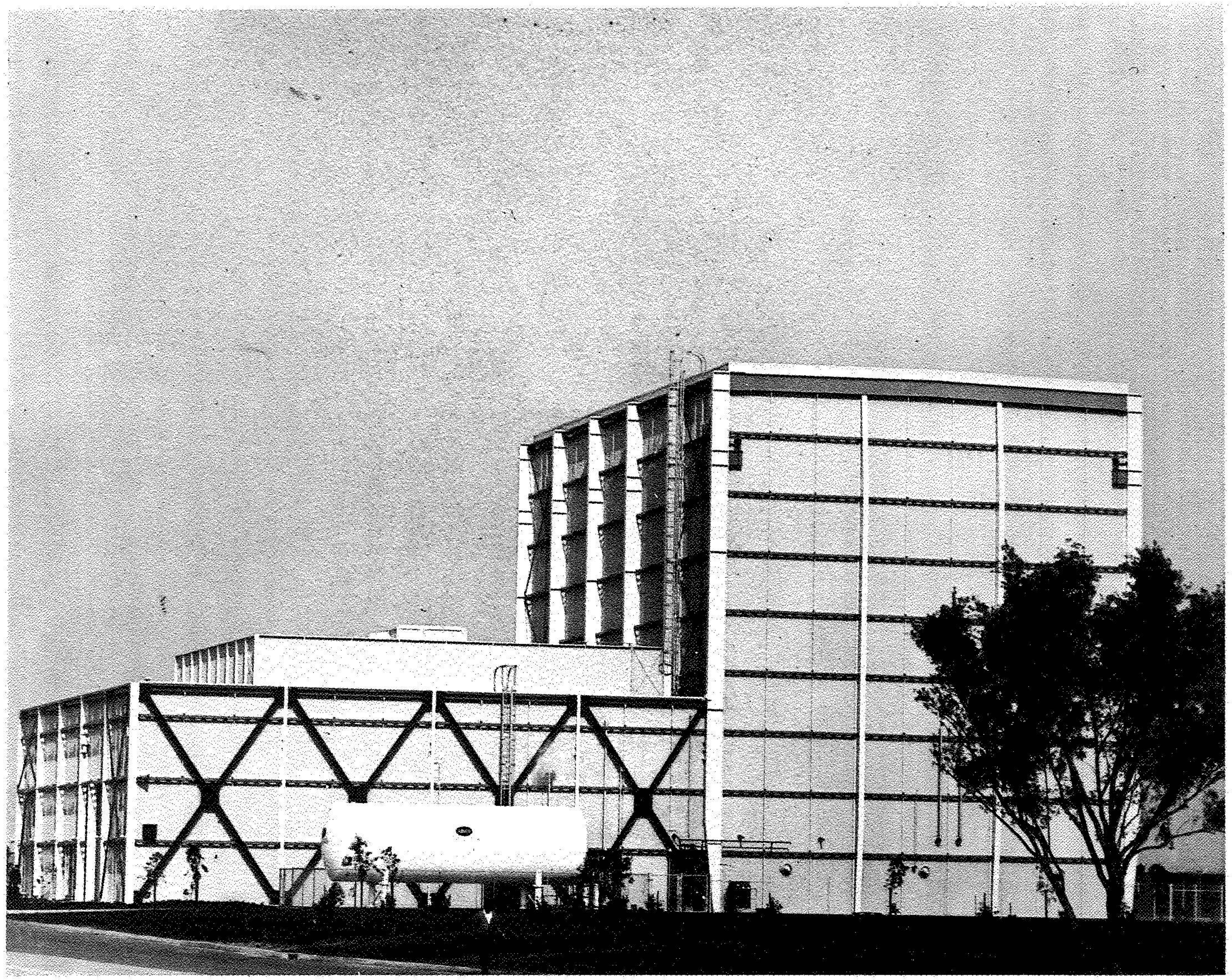


CHAMBER 14
SPACE SIMULATION LABORATORY
DOUGLAS AIRCRAFT COMPANY
DOUGLAS SPACE SYSTEMS CENTER
HUNTINGTON BEACH. CALIFORNIA



CHAMBER 14
SPACE SIMULATION LABORATORY LAYOUT

SPACE SIMULATION LABORATORY
DOUGLAS AIRCRAFT COMPANY
DOUGLAS SPACE SYSTEMS CENTER
HUNTINGTON BEACH, CALIFORNIA



CHAMBER 14
SPACE SIMULATION LABORATORY
DOUGLAS AIRCRAFT COMPANY
DOUGLAS SPACE SYSTEMS CENTER
HUNTINGTON BEACH, CALIFORNIA

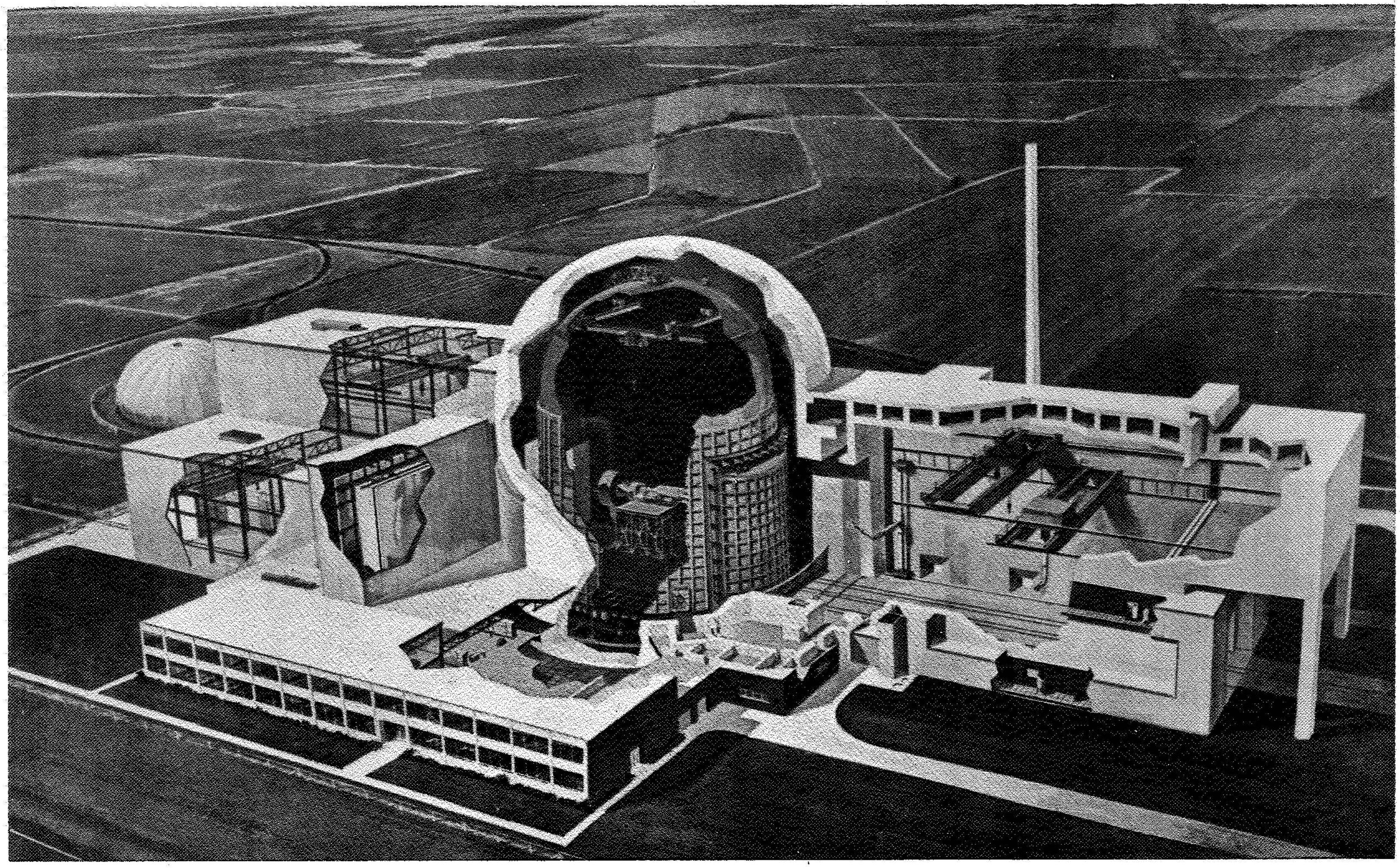
APPENDIX D

NUCLEAR POWER TEST FACILITY

Characteristics are listed below for an environmental nuclear test facility which is presently under construction.

Agency and location:	NASA Lewis Research Center Plumbrook Station, Ohio
Name of facility:	Space Propulsion Facility (Nuclear)
Purpose of facility:	Testing of SNAP-8 and Apollo spacecraft
Size:	100' dia x 122' high
Work space dimensions:	50' x 100' x approx 80' high; two 50' x 50' side opening doors for loading chamber
Maximum size of test article:	To fit within work space dimensions above
Materials handling equipment:	Yes (cranes and manipulators)
Man-rated:	No
Minimum operating pressure:	1×10^{-8} torr
Pumping speed:	Diffusion pumps - 1.5 million liters/sec; 100°K Condensables (LN_2) - 500 million liter/sec; 20°K Condensables (GHe) - none
Time to achieve minimum pressure:	24 hours
Type of pumping system:	32 - 54" diffusion pumps initially; provision made for 44
Temperature range:	-300 F to ambient
Type of thermal system:	Cold only
Cryogenics:	Liquid nitrogen cooling; future gaseous helium cooling to approx 420 F, auxiliary cooling employed in shrouds around the test article to -420 F

Solar Simulation:	None initially. Provisions made for future addition of 500 sq ft solar simulation
Other environmental capabilities:	Provision made for future vibrator in center of chamber. No other motion simulation
Supporting items:	
Instrumentation:	300 channels
Additional information:	Planned for 90 day tests Normal heat load 100-200 KW Entry to chamber through two 50' square doors
Status:	Under construction with completion scheduled for early 1967



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